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Intermountain Forest and Range Experiment Station

General Technical Report INT-109

March 1981

Proceedings of Intermountain Nurseryman's Association and Western Forest Nursery Association

Combined Meeting

August 12-14, 1980
Boise, Idaho

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"WELCOME"

by

Ralph Peinecke
Vice President Timberland Resources
Boise Cascade Corporation

for the

Joint Meeting
Intermountain Nurseryman's Association
Western Forest Nursery Council

Boise, Idaho
August 12, 1980

Thank you, Dick, and good morning ladies and gentlemen. I appreciate the opportunity to take part in the combined meeting of these two organizations, whose work is so important to us all.

To those of you from other regions of the country, Canada and elsewhere, I would like to welcome you to Boise and to the Intermountain West. While your agenda over these three days is a busy one, I trust you'll be able to enjoy our community and Southwestern Idaho. Although Boise Cascade Corporation has grown over the years to touch many parts of North America, the company's roots are here in the Intermountain West, and we're very proud of it.

As the opening year of a new decade, this seems like an appropriate time to stop and look at where we are, and see what the future holds for forestry. As a matter of fact, the National Forest Management Act requires that we do just that.

As this nation charts its future for managing our abundant timberlands, a point which the American philosopher Will Durant left us with is worth repeating. Durant observed that "At 20, I knew everything and my father knew nothing. But when I was 30, I was surprised to see how much my father had learned during the past 10 years."

As I look back, I can relate to what Durant was saying. I'm sure you can too.

In growing the timber for a whole spectrum of forest products which have contributed so much to society over the past 200 years, and has helped raise our standard of living to unprecedented heights, we have learned a lot about growing trees. Especially in the past 20 to 30 years, forest management has advanced dramatically. Developments in genetics research, mechanization, computer sciences and other technologies have brought about quantum gains in our ability to increase the potential productivity of timberlands for many uses.

In looking over the agenda for this seminar a few days ago, I was impressed by the range and depth of subjects to be covered here. The information to be exchanged will certainly be valuable. It must be, because each of us here today is faced with a very major challenge. Today's and tomorrow's forests must provide for dramatically increasing social and economic needs. Domestic demand for paper and wood products, according to the Forest Services's Resource Planning Act assessment, will more than double within the next 50 years.

Between 1976 and the year 2030, demand will rise from 13.3 billion cubic feet to 28.7 billion cubic feet. And largely, with the exception of the shorter crop rotation areas of the South, it will be the trees already in the ground today that must meet this need. And it is to the credit of those in the audience that many of those trees in the ground today that will help sustain this harvest were developed in your nurseries.

If I sound concerned about this challenge, I want you to know that in fact, I am. On the one hand, the expanse and productive potential of this nation's forests is so great, that not only can the public demand be met, but, at the appropriate time, the U.S. could become the world's wood products basket, the major supplier to other nations of building materials paper and related products. But ironically, we know that present levels of forest management are inadequate.

Forests comprise about one-third of the U.S. land mass. Of these timberlands, about 500 million acres are classified as commercially productive. And of these commercial acres, more than half are almost totally unmanaged.

Industry owns 14 percent of this commercial timberland base, and provides 37 percent of the nation's softwood fiber supply. The federal government controls 20 percent of the U.S. commercial timberland base but only supplies 23 percent of the harvest. The remaining 40 percent of the harvest comes from the 66 percent of the resources held by the non-industrial private and other public ownerships.

With only 16 percent of the U.S. commercial timberland base, the forest industry accounts for over 50 percent of new tree planting and direct seeding; 50 percent of timber stand improvement carried out on non-federal land, and produces more than 40 percent of the tree nursery stock.

In Oregon and Washington alone, industrial nursery capacity has grown from 26 forest tree nurseries in 1973 to 53 nurseries operated today by the Industrial Forestry Association and other private interests. Annual capacity in these nurseries now totals more than 300 million trees, of which 60 million are container production. And on all industrial lands in Oregon and Washington, the forests being replanted each year exceed the number of acres being clearcut harvested by some 10,000 acres -- and this planting trend is increasing.

As a result of these and other efforts, the annual growth of timber on industry lands is closer to full production potential than on lands in any other ownership classification. Certainly, the commercial forest areas on the National Forests must be managed for objectives beyond timber production alone. But it has been clearly demonstrated that greater fiber productivity is compatible with increased recreation opportunities, wildlife propagation and clear waters. A very good example of this is the Big Creek salmon and steelhead hatchery located just downstream from some Boise Cascade timberlands in northwest Oregon. The story of this timber shed and fish hatchery is featured in a magazine called the BOISE CASCADE QUARTERLY. For those interested, copies of the QUARTERLY and a descriptive brochure called BOISE CASCADE FORESTS are available on the literature table.

Meeting the challenge of increasing fiber demand will take a combination of time, money, silvicultural know-how and responsible management by government, industry and the private non-industrial sector. If money grew on trees, our problems would be over. But the reality is that trees grow on money, hence, substantial investments must be made to achieve greater forest productive potential including increased investments in forest nurseries and nursery research. That money must be backed up by a lot of faith and conviction, since the focus of timber investment is very long-term.

A major trade association estimates that industry, for example, must generate more than $3 billion dollars annually to cover all necessary costs of acquisition, reforestation, maintenance, silviculture, taxes, interest, roads and other management aspects. Adequate levels of investment also are needed on private non-industrial and government lands to bring them up to the needed levels of fiber growth and yield.

Investment in the private sector -- both industrial and non-industrial -- can be encouraged by far-sighted, responsible regulation and legislation. Excessive restrictions and taxation levels that discourage needed investments will do nothing to avert a wood fiber shortfall. The national economy, and ultimately, the American consumer, will be the losers. This just isn't necessary.

Certainly, it is highly important to address the growing of new trees. And it is equally necessary to address ourselves to the need for responsible management of existing forests, including control of destructive pests such as the gypsy moth, the pine bark beetle, the tussock moth and the spruce budworm that has heavily infested large acreages in this and other regions and absolutely must be controlled.

Having the tools to practice silviculture is critical to responsible forest management. I'm highly concerned that we are losing necessary tools such as pesticides and herbicides that are proven to be safe and effective, without having developed suitable replacements for these forest chemicals.

In recent years, through work being done by organizations and individuals such as those of you here today, we have truly begun to understand that we can manage and control the volume, qualities, and form of wood fiber and its many products. Based on the promise of new research and development, forest management programs of the year 2000 might make some of today's practices look rudimentary by comparison.

To see that this potential to provide fiber can be realized, here are some things that I would <u>ask</u> you to do beyond the work that you're presently involved in:

- o Work to promote understanding of the fact that government, industry, private landowners and conservationists should be allies in forest management. It is time to accentuate the positive by firmly establishing common areas of agreement instead of adding to the cycle of action and reaction.

- o Second, be vocal about the need for government and its regulatory agencies to improve the climate for capital investment in timber productivity. Let's encourage investment that is in the public interest.

- Next, give vigorous support at all levels of government to legislation promoting wise use of national resources. A good place to start on this is to give active support to the release of productive commercial forest lands that were studied in the Forest Service's Roadless Area Review and Evaluation but not recommended for wilderness designation.

Through these public policy actions, we can contribute even more to the shaping of the future of forestry. There was never a more important time for it.

I'd like to leave you with a thought often expressed by Boise Cascade's chief forester. He says it is a lot of fun to manage a big, thriving second growth forest because you can play the role of a physician. But if you're managing an overmature old-growth forest, you're somewhat akin to a mortician.

Most of us in this profession, I'm sure, would rather be the physician. In fact, those of you in the audience might think of yourselves as being somewhat of a pediatrician. It all starts with the work you're doing. Having brought the baby into the world, none of us wants to leave it out there to perish.

Thanks for this opportunity to be with you today. I'm sure that you will have a very successful seminar here in Boise.

EMERGING RESOURCE TRENDS IN THE 80'S[1]

R. Max Peterson, Chief[2]

Nothing is more universally expected of a forestry agency than that it be able to plant and grow high-quality trees. Our future timber supply is directly connected to the sufficiency of our reforestation effort. Most other values of the forest--wildlife, water supply, beauty--are connected with adequate forest cover. So, it is appropriate that we are commemorating the Forest Service's 75th anniversary with a tree-planting campaign.

You know the trends as described in our RPA Assessment--more people, more disposable income, more leisure time, and greater demands on the forests. These trends have already shaped nursery management--there are more nurseries, larger nurseries, more seed sources, speeded-up seedling production, and more sophisticated cultural practices. It is gratifying to look at the nurseries developed in the past two decades--much progress has been made in nursery practices. This progress is one of the key ingredients to the gains we have made in long-term forest growth.

But, more must be done if we are to meet the demands continuing to press on public and private forest lands alike. First, the demand for high quality planting stock will continue to grow. A recent legislative expression of our concern for reforestation is the NFMA's requirement that we budget to eliminate the feasible reforestation backlog on National forests by 1985. By October of 1979, we had reduced the backlog from 3.1 million acres to 882,000 acres--half by actual reforestation, a quarter by land reclassification, and a quarter through natural regeneration. Of this remainder, it is feasible to reforest about 566,000 acres and the proposed budget level for 1981 is sufficient to stay on the schedule of removing this backlog by 1985 if adequate funds are provided in future years. In all cases, we will need first-rate planting stock.

We are expanding our nursery capacity--our estimates show a need for about 269 million seedlings from Forest Service nurseries over the next several years. This will meet our needs as well as those of BLM and other cooperators. There is a huge reforestation job ahead on private lands, too. In the Pacific Northwest and coastal Alaska, more than 75 percent of the nonstocked lands are on highly productive sites. We are particularly concerned about the amount of private, nonindustrial forest land in the South that is not reforested after harvesting--over a 10-year period, 7 million acres of pine forest were replaced by less desirable species or remained essentially unstocked. Our long-term program will provide assistance to motivate landowners to reforest and to use genetically-improved stock. Our goal is to nearly quadruple the amount of private-land reforestation each year. We are working with the Dept. of the Treasury to analyze tax incentives to encourage landowners to reforest their lands.

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[1] Speech presented at Intermountain Nurseryman's Association, Western Forest Nursery Council, Joint Meeting, Boise, Idaho, August 12/13/14, 1980.

[2] Chief, R. Max Peterson, USDA Forest Service, Washington, D.C. 20013

A second trend is the growing complexity of nursery work--tailoring seed sources and seedling characteristics to site requirements and to meet the diverse needs of wildlife, esthetics and energy production. The complexity of nursery work will probably prompt increased computerization, greater specialization and the growth of Nursery staffs. Third, nursery management is becoming world-wide in scope--nurserymen search the globe for the materials or knowledge needed to improve forest in their own nations.

A fourth trend is the growing importance of nursery research and the application of research results. Research can help develop cost-saving cultural practices or equipment, or ways to protect expensive plant materials from insects, disease or other damage. Conferences such as this are immensely valuable in getting this research knowledge into practice.

The trends of growing demand for the quantity and quality of seedlings, the increased complexity of nursery work, broadening international interest, and continuing scientific progress add up to a decade of immense opportunity and challenge.

CANADIAN NURSERY UPDATE[1]

Ralph F. Huber[2]

INTRODUCTION

The 1981 meeting of the Intermountain Nurserymen's Meeting will be held in Edmonton, Alberta, Canada, August 11 - 13. Many of you will be attending your first Nurserymen's Meeting outside of the United States. In order to acquaint you with the nurseries you could visit in Canada, I will outline nursery production first on a national basis and then in detail for the western and northern region in which Alberta is located.

NATIONAL SUMMARY

Bare-Root Seedling Production

In 1979, approximately 205 million bare-root seedlings were shipped from 46 production centres across Canada to the field for reforestation and afforestation purposes (Table 1).

Table 1.--National summary of bare-root seedling production

Province	No. of production centres	Area available for production (ha)	Area currently in production (ha)	Production 1979 ('000)
British Columbia	8	806	278	66,730
Alberta	2	193	99	3,400
Saskatchewan	5	308	219	16,230
Manitoba	1	19	4	1,432
Ontario	12	693	536	62,370
Quebec	10	284	176	30,875
New Brunswick	3	166	147	20,300
Nova Scotia	2	98	18	2,900
Prince Edward Island	1	34	0.4	300
Newfoundland	2	245	42	300
	46	2,846	1,517	204,837

[1]Paper presented at the combined meeting of the Western Nursery Council and Intermountain Nursery Man's Association, Boise, Idaho, August 12-14, 1980.

[2]Nursery Production, Northern Forest Research Centre, Canadian Forestry Service, Edmonton, Alberta, Canada.

Production for 1980 is estimated at 228 million seedlings, an increase of approximately 11% over 1979.

Containerized Seedling Production

In 1979, 108 million containerized seedlings were shipped in a variety of container types from 47 production centres across Canada (Table 2).

Table 2.--National summary of containerized seedling production

Province	No. of production centres	Production 1979 ('000)	Heated (No.)	Heated (Area m^2)	Non-heated (No.)	Non-heated (Area m^2)
British Columbia	10	34,307	73	28,608	19	7,812
Alberta	5	20,620	35	17,343	-	-
Saskatchewan	2	1,860	3	1,180	-	-
Manitoba	1	645	4	622	-	-
Ontario	8	10,240	22	5,361	16	4,067
Quebec	3	772	6	1,277	-	-
New Brunswick	9	32,312	46	21,135	7	4,670
Nova Scotia	6	5,946	14	4,322	18	4,918
Prince Edward Island	1	1,200	1	1,860	-	-
Newfoundland	2	556	4	1,168	-	-
	47	108,458	208	82,876	60	21,467

Shipments for 1980 are estimated at 124 million seedlings, an increase of approximately 14% over 1979.

Currently, Canada has 104,343 m^2 of growing area available for the production of containerized stock in federal, provincial, industrial and private greenhouse facilities. Seventy-nine (79%) percent of this area is in 208 heated greenhouses.

The popularity of container types used varies across the country (Table 3).

Table 3.--Container types used in Canada

Province	Container Type
British Columbia	-BC/CFS Styroblock 2A and 4 -Spencer-Lemaire 'Fives' Rootrainers
Alberta	-Spencer-Lemaire 'Ferdinand', 'Fives' and 'Hillsons' Rootrainers
Saskatchewan	-FH 408 Japanese Paperpot -FH 315 & FH 408 Japanese Paperpot
Ontario	-FH 408 Japanese Paperpot -Spencer-Lemaire 'Ferdinand' Rootrainer

Quebec	-BC/CFS Styroblock 2A and 4 -Spencer-Lemaire Rootrainers
New Brunswick	-FH 408 Japanese Paperpot -Can-Am 45 cc Multipot
Nova Scotia	-FH 408 Japanese Paperpot -Can-Am 80 cc Multipot
Prince Edward Island	-Spencer-Lemaire 'Ferdinand' Rootrainer
Newfoundland	-FH 408 Japanese Paperpot -Spencer-Lemaire 'Fives' Rootrainer -Can-Am 43 cc Multipot

WESTERN AND NORTHERN REGION

Within the region there are eleven facilities producing bare-root seedlings, container seedlings, or a combination of both, for reforestation or afforestation (fig. 1). Production at different nurseries varies from twenty million to two hundred and fifty thousand. Table 4 gives a regional production summary.

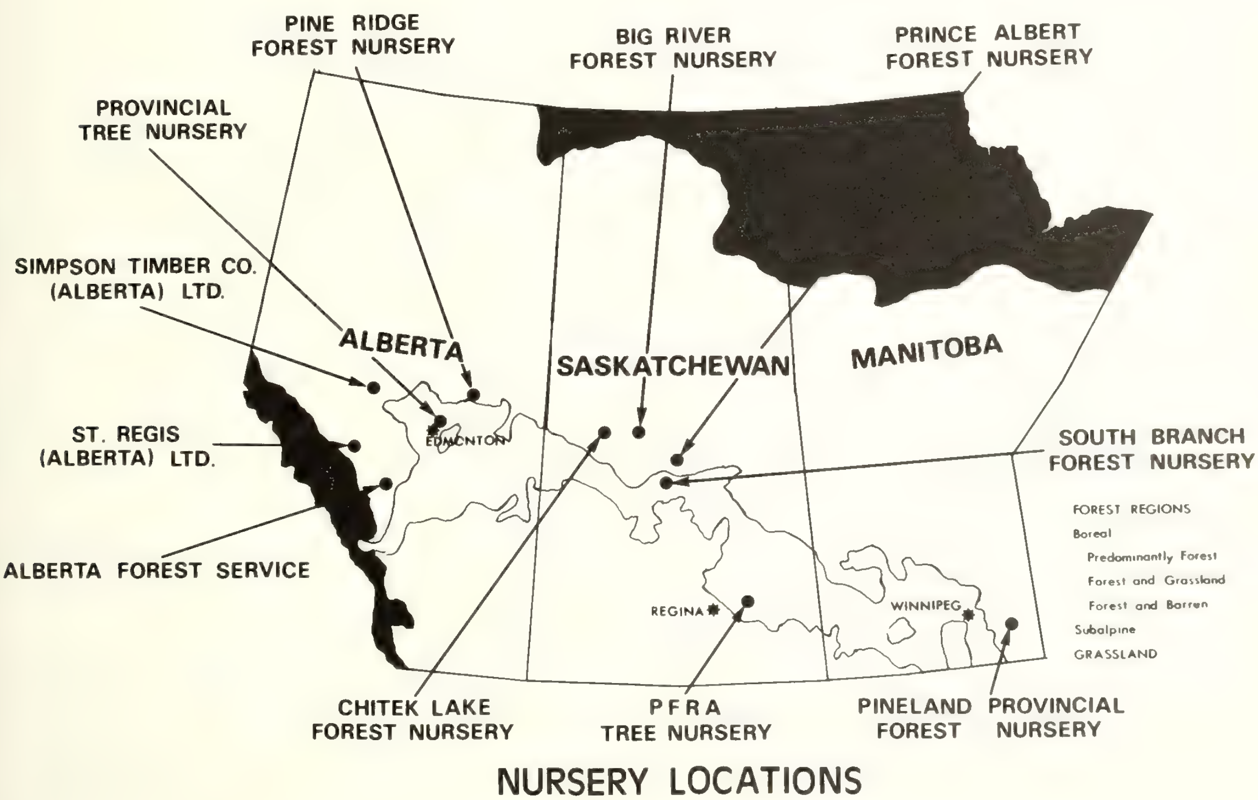

Figure 1.--Location of Nurseries in the Western and Northern Region.

Table 4.--Western and Northern Region summary of nurseries

	Bare-root	Container
Number of Production Centres	8	8
Area Available for Production	520 ha	19,145 m^2
Area Currently in Production	322 ha	19,145 m^2
1979 Production ('000)	21,062	23,125
Estimated 1980 Production ('000)	30,150	22,060
Number/Area Heated Greenhouses		42/19,145 m^2

HI-LITES OF SELECTED NURSERIES

Some of the nurseries within the region have unique systems or machinery for accomplishing certain tasks. They are as follows:

Nursery	Unique characteristics
Pineland Provincial Forest Nursery Hadashville, Manitoba	Rolling greenhouses--when one crop of seedlings is ready to be moved out, they roll greenhouse to new location and start second crop.
PFRA Tree Nursery Indian Head, Saskatchewan	Highly mechanized. Assorted seeds for different species. Good lifting system. Modern cold storage.
Prince Albert Forest Nursery Prince Albert, Saskatchewan	Large glass greenhouses. Automatic boom sprinklers. Complete paperpot filling system. New seed extraction plant.
Pine Ridge Forest Nursery Smoky Lake, Alberta	Very modern facility. Twenty (20) greenhouses. Pallet system for containers. Tree breeding facility. Automatic filling system for containers. Seed extraction plant.
Provincial Tree Nursery Oliver, Alberta	Growing many different species in containers. Propagation trials.
Simpson Timber (Alta.) Ltd. Whitecourt, Alberta	Container Production Greenhouse with travelling boom for both water and lights.
St. Regis (Alberta) Ltd. Hinton, Alberta	New glass container production facility. Set up to grow 12 crops of 240 m each per year.

FORESTATION CONCEPTS AND PRACTICES

DEVELOPING IN NEW ZEALAND[1]

Richard W. Tinus[2]

In New Zealand government and industry are developing a new nursery system backed by substantial research facilities and budget. Beds of radiata pine are precision sown and thinned to square spacing of 7 x 7 cm. This permits "box pruning" which is horizontal undercutting plus vertical root pruning along and across the bed. When lifted, a box-pruned seedling retains virtually all of its roots, and almost every tree is shippable. Since culling and counting are not necessary seedlings can be lifted and packed in the field, eliminating the need for a packing shed. Reduction in exposure and handling of seedlings increases plantation survival and initial growth, and promises to reduce rotation age by 1 year and decrease nursery costs.

Radiata pine of all ages has been successfully propagated from cuttings.

In August 1979, I attended an International Union of Forestry Research Organizations workshop in New Zealand on "Techniques for Evaluating of Planting Stock Quality." I toured facilities where new concepts and products in forestation are being developed to meet New Zealand needs. Some of these practices seem applicable in this country.

New Zealand currently has about 750,000 h of planted radiata pine. This single, introduced species has become the major basis of New Zealand wood production for domestic consumption and export. Radiata pine is very fast growing in New Zealand, with a first thinning and pruning at age 7 and a rotation age of between 27 and 30 years. Final tree sizes are 60 cm in diameter and 30 m tall. On the best New Zealand sites, radiata pine reaches 40 m in 20 years. Because of New Zealand's distance from major international markets, New Zealanders need to raise trees very cheaply and efficiently. Hence, they invest a great deal of money and manpower in forestry research.

Slide 1. The federal Forestry Research Institute at Rotorua is engaged in many projects, but a great deal of effort is spent improving nursery practices. This is the only nursery I know of devoted solely to research.

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[1]Paper presented at a joint meeting of the Intermountain Nurseryman's Association and the Western Forest Nursery Council, Boise, Idaho, August 12-14, 1980.

[2]Plant Physiologist, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Bottineau, N. Dak.

Slide 2. New Zealanders are developing a comprehensive regeneration system which begins in the nursery and is followed through transportation, planting, and aftercare. The concept begins with square spacing in the nursery beds. This is in contrast to conventional beds in which seedlings are much closer within the row than between rows. Research at Rotorua is in progress to determine the spacing necessary to produce the desired seedling.

Slide 3. Square spacing of these seedlings increases from 3 x 3 cm to 10 x 10 cm left to right. At present, it looks as though 7 x 7 cm spacing is optimum for radiata pine. Square spacing is achieved by seeding precisely and thinning. For seeding the Ojyard[3] seeder is used, which is good, but not perfect. Of course, the seed is also good, but not perfect. After germination, the beds are thinned. This expensive hand operation has not yet been mechanized, but at the moment it is the only way to achieve square spacing.

Slide 4. The purpose of square spacing is twofold: First, it enables the seedling to make very efficient use of the available space. Second, it permits "box pruning," which is pruning the root system of each seedling on 4 sides and the bottom. Undercutting and along-the-row pruning have been mechanized, but across-the-row root pruning has not.

Slide 5. Undercutting is for the purpose of developing a fibrous and compact root system in the soil zone that will be lifted. Undercutting severs the taproot cleanly. It is done with a thin, sharp blade on a reciprocating undercutter. The blade is similar to a bandsaw blade and is changed at the end of each row. Undercutti does not lift the seedlings. When undercut at a depth of 10 cm, you can barely see the tops wiggle as the blade passes under them. All radiata pine at Rotorua is raised as 1-0, and undercutting is generally done twice, first at a 10 cm depth, and later at 12-15 cm.

Slide 6. By switching to a heavy blade and tilting it about 20^{o}, this same machine can be used for "wrenching." The wrenching blade need not be particularly sharp, because it does not cut anything. It passes completely under the seedlings, lifts them and the soil, loosening the root to soil contact. The purpose is to stress the seedling to stop the terminal elongation and enable the seedling to better withstand subsequent stress especially after outplanting.

Slide 7. A box pruned seedling is lifted with virtually all of its roots intact in a compact volume that can be planted with little root damage. There are no long stringy roots that need to be pruned at packing to prevent a poor planting.

Slide 8. In the New Zealand climate, radiata pine behaves similarly to southern pine. That is, it can be planted successfully with comparatively few roots compared to the shoot. If you look carefully at the seedling in this slide, you can see the two levels where it has been undercut. The pencil indicates the lowermost point of undercutting. The first cut was about 5 cm above that, immediately below the major horizontal spray of roots. Seedlings are first undercut at a shallow depth and later undercut somewhat deeper.

In North America, there seems to be disagreement among nurserymen as to the value of wrenching, and I can suggest several reasons why this is the case. First, not all nurseries have the proper equipment. A reciprocating undercutter is essentia

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[3]The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

for both undercutting and wrenching. Second, the soil must be suitable. The soil at Rotorua is a very friable volcanic ash soil with few rocks and very little sticky clay in it. Because of the soil, I see many difficulties in developing proper wrenchin regimes at nurseries like Lucky Peak at Boise or Big Sioux Conifer Nursery at Watertown Third, the timing of undercutting and wrenching must be in accord with the physiology of the tree. It is not possible to take the New Zealanders' schedule, transpose seasons to the northern hemisphere, and apply the schedule mechanically. Each species grown and nursery location may need research to develop an appropriate schedule.

Slide 9. A crucial aspect of the New Zealand concept is the reduction of seedling handling in the nursery, during transportation, and in storage. This has both biological and economic advantages. Having been thinned and box pruned by the time the seedlings are ready to be lifted, virtually every seedling is shippable. Thus, there is no need to grade and count them. The number of trees shipped can be computed from how many meters of bed are lifted. The seedlings can be packed in the nursery bed as they are lifted. The seedlings are packaged in rigid boxes which protect the seedlings from crushing. This eliminates broken buds and bruised tissues which release metabolit and encourage the growth of pathogens. The boxes filled with seedlings at the nursery bed are placed in insulated coolers and shipped to storage or to the field. At the planting site, the shipping box is clipped onto the planter's belt, becoming the planting box.

Slide 10. Shipping and storage containers are insulated but not refrigerated. Seedlings are not stored for more than a few weeks, often only a day or two. The weather is cool, usually cloudy, and frequently rainy during the shipping and planting season, so this method of storage has proven quite satisfactory. However, it could be readily adapted to refrigerated or frozen storage.

Slide 11. New Zealand foresters have good reason to believe that their proposed system will produce better trees in a shorter period of time. On the right side of the picture are trees produced and planted by the current operational system. That is, trees are lifted in the field, taken to a shed for culling, root-trimming, and packing into bags. Then they are stored and shipped out to the field for planting. On the left are seedlings that have been thinned, box pruned, and packed into boxes at the nursery bed and outplanted from these same boxes. Survival and growth of this group are clearly superior to those handled by the current system. This entire plantation was put in by the same planting crew.

Slide 12. Other plantings show the same comparison. These seedlings were packed in bags in the shed.

Slide 13. These seedlings were packed at the bed. Not only does the survival increase, but equally important is the increased growth that may shorten the rotation by a year.

Now with all this research, you would think that the new techniques would be quickly and readily adopted by the operational nurseries. However, as in other parts of the world, especially government operations, this is not necessarily the case.

Slide 14. Here we are at the Kaingaroa Nursery, which grows radiata pine seedlings for the Kaingaroa Forest. Notice that these seedlings do not look quite as good as the ones grown at the research nursery in Rotorua, partly because this nursery is 300 m higher in elevation and most of the stock produced is 2-0.

Slide 15. The spacing is not very uniform. The seedlings are not as large or as good in color.

Slide 16. The range of seedlings lifted at the nursery runs from excellent to just passable.

Slide 17. In the packing shed I saw much unnecessary root exposure. Fortunately, it was a cool, cloudy day.

Slide 18. After the trees are selected and bundled, the roots are pruned; thus maximizing the shock to the tree. This operation could be eliminated by box pruning.

Slide 19. The seedlings are assembled in half 15 gallon barrels,

Slide 20. And unceremoniously dumped into plastic bags,

Slide 21. Which are then moved by a rather ingenious conveyer,

Slides 22 & 23. Into a storage facility, which is well insulated, but not mechanically refrigerated.

Slide 24. New Zealand foresters do train their planters, however, and some of the devices for doing so might well be emulated. Here is a cartoon showing how to do everything wrong. I'm sure most of you already know the techniques.

Slide 25 & 26. Next, an illustration of how to do it right, starting with thinning in the nursery, packing in the bed in rigid boxes, storing the boxes in a large insulated container which is handled mechanically, and planting from the boxes at the planting site. Stress is layed on minimizing handling and exposure.

Slide 27. This is supplemented by photographs showing do's and don'ts.

Slide 28. Another aspect of raising radiata pine is that it can be propagated vegetatively.

Slide 29. Cuttings from trees under 7 years of age root readily in the field. Government and industrial foresters are using this method to extend the propagules of superior trees for commercial operations. The New Zealand climate and tree species permit this, but I doubt that it would be successful with most of the species we grow in the United States.

Old radiata pine, however, do not root readily, and rooting has all of the problems encountered with many other pine species. Researchers at Rotorua have found a way to root scions successfully, however. First, branch tips are girdled after shoot growth has been completed in mid-summer. The girdle is waterproofed with vaseline and covered with aluminum foil. This is not an air layer, however. The scion will callus at the base, but not root. At the same time, major buds are picked off the scion.

Slide 30. About 4 weeks later, after the girdle is well calloused and new small buds have developed on the terminal, the scion is cut and transferred to a small bedhouse covered with white poly. The scions overwinter unrooted. In the spring, rooting occurs, as well as bud break. After the scions appear to be established, they are lifted and the roots pruned back to within a few millimeters of the original callus, placed in jiffy pots and allowed to root again. This time they produce roots that are functional and have normal anatomy. When the roots penetrate the jiffy pots, they are considered ready to go to the field. I am testing this technique on Scotch pine and ponderosa pine, and will know in another year whether or not it will work.

Slide 31. It certainly works for radiata pine. One of these rows is from seedlings and the other is from cuttings. You can see they are equally good.

Slide 32. New Zealanders are also studying tissue culture and are at the point where cultures from cotyledons and the female gametophyte are expected to be used for operational plantings within 2 years.

Slide 33. Seedlings produced by tissue culture look normal, healthy, and very uniform.

Slide 34. Another of the facilities at Rotorua is probably the world's tallest growth chamber. There is room for a crowd of 12 people and 4 trees in a chamber 3 stories high.

Slide 35. The trees are growing in containers 3 m on a side with transparent walls, so that the roots can be inspected.

Slide 36. Another controlled environment facility is at Palmerston North--the Climate Laboratory, designed, built, and run by the Plant Physiology Division of the Department of Scientific and Industrial Research. The Forestry Institute is currently running experiments in this facility on hardiness, but the facility is available to the New Zealand scientific community in general.

Slide 37. To the greatest extent possible the machinery controlling the environment is outside the chamber.

Slides 38 & 39. The Climate Laboratory has displays showing what they can control in those growth chambers.

Slide 40. Seedlings can be subjected to both radiation and advective freezes. As a matter of fact, they can create snowstorms in this facility. Those of you who know anything about mechanical refrigeration will appreciate how difficult it is to create an event like this.

Slide 41. The Climate Laboratory now has for radiata pine curves of frost tolerance versus time of year. These are used to determine suitability of planting stock for a given site, for determining planting dates, and for tree improvement purposes.

Slide 42. The University of Canterbury at Christchurch is engaged in studies on the growth rate and potential of trees. There is a quarter of a million dollars worth of field equipment packed into two trucks and taken out to the field.

Slides 43, 44, & 45. A cuvette, for measuring photosynthesis and transpiration, is placed on the branch to be tested. Light can be added using a Xenon arc mounted on a boom.

Slide 46. The controls and data logging equipment are inside one of the trailers.

Slide 47. Not every tree planted in New Zealand is radiata pine. There are some areas where protection plantings are needed to control soil erosion on steep hill sides. The Forest Research Institute at Christchurch is testing many other exotic species and provenances, including ones that are important commercial timber trees in North America, such as lodgepole pine, ponderosa pine, Douglas fir, and western larch.

Slide 48. New Zealanders are not particularly impressed with the growth rate of these species, but it appears to me that they are growing as well here as they do in their native range. In other words, although the primary purpose of these plantings will be protection, it is quite clear that they are also producing very useable amounts of wood.

Slide 49. Biomass measurements are made to determine growth rate. This is Scotch pine being harvested, and the needles, branches, and trunk of each tree are being weighed.

Slide 50. In the short time that this stand of trees has grown, it has already made significant changes in the soil on the site. The brown A horizon has been added by the trees.

Slide 51. Many of these upland plantings have been container grown, and New Zealanders have discovered what others around the world have found, that the container is best removed before the tree is planted.

Slide 52. New Zealanders have made extensive studies which indicate that for them the styroblock is more suitable than either direct seeding or the Walter's bullet.

Slide 53. New Zealanders have also reinvented some planting tools: The brown one is a New Zealand version of the Finnish potiputki, which they claim is much more rugged, and cannot be broken even by the roughest planting crew.

REPORT ON THE NORTH AMERICAN FOREST SOILS WORKSHOP[1]

Thomas D. Landis[2]

ABSTRACT

The purpose of the workshop was the need for a technical update on forest nursery soils. Highlights of the workshop indicate, generally, that maintenance of proper soil structure is essential; a certain soil moisture should be maintained; seedling survival increases with decrease in seedbed density; etc. The entire proceedings of this workshop will not be available until 1981, however, the results of the workshop indicate that soil is an essential phase of nursery soil management and deserves continued study.

INTRODUCTION

This workshop developed as a result of the increased awareness of many nurserymen that a technical update on forest nursery soils was sorely needed. The first such workshop was held in 1965 and the state-of-the-art has undergone obvious changes in the past 15 years.

This workshop was held during the week of July 28-August 1, 1980, at the College of Environmental Science and Forestry of the State University of New York at Syracuse. It was jointly sponsored by the USDA-Forest Service, the Canadian Forestry Service, and the University.

It was appropriate that the workshop was dedicated to the memory of Dr. A.L. Leaf, who was such a vital force in the study of nursery soils. Dr. Leaf was one of the principal organizers of the workshop and his untimely death last summer threatened its existence. Only through the special efforts of Dr. Leaf's friends and coworkers could the work have gone on as planned.

The workshop attendance was truly remarkable, with nurserymen and forest scientists from across the United States and Canada. The official registration totaled 180, of which 34 were Canadians. The participants formed an ideal mixture of practicing nurserymen and leading researchers.

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[1]Report on the North American Forest Soils Workshop, College of Environmental Science and Forestry of the State University of New York at Syracuse, New York, July 28-August 1, 1980.

[2]Westwide Nursery and Greenhouse Specialist, USDA-Forest Service, State and Private Forestry, Lakewood, Colorado.

OBJECTIVES

The objectives of the workshop included: (1) To review basic concepts of forest soils as they apply to modern nursery management; (2) to discuss soil testing procedures and their meaning to nurserymen; (3) to develop the proceedings into a reference book for the special field of nursery work.

FINDINGS

The proceedings of this conference will not be available until next year, so I would like to pass along certain highlights, which you may find of interest:

On seedling grades and quality

1. Stem diameter or caliper is the best single morphological index of seedling quality.
2. Plant moisture stress and root regeneration capacity are the best physiologic measures of seedling quality.
3. Seedling outplanting survival increases with a corresponding decrease in seedbed density. Examples: pines 18-25/sq. ft.; spruce 25-30/sq. ft.

Soil physical properities

1. Soil structure is one of the most critical aspects of nursery soils because, for practical purposes, long-term changes are not possible.
2. Maintenance of proper soil structure is essential because soil pores are more important than soil solids.
3. Organic matter sources are becoming limited and the best solution may be to grow your own.

Irrigation practices

1. Soil moisture retention curves are necessary for proper irrigation scheduling
2. As the quality of irrigation increases, differences in fertilizer responses disappear.
3. Soil moisture levels should be maintained between 0.3-1.0 bar of tension, which is more moist than traditional recommendations.

Soil Biology

1. Soil fumigants are most effective against pathogenic organisms and usually cannot be economically justified for weed control alone.
2. Newly registered herbicides have not adversely affected mycorrhizal levels in nursery soils.
3. A commercially available ectomycorrhizal inoculum is being tested and may be available if marketing problems can be overcome.

Soil fertility

1. Considerable growth loss occurs before visible symptoms of nutrient deficienc become apparent.
2. High soil pH and salinity levels are a site selection problem, but can be overcome by proper soil and irrigation practices.

Cultural practices

1. Seed stratification periods should be lengthened beyond the Woody Plant Seed Manual recommendations, as these data were obtained under laboratory environments.
2. Management practices, such as bed density, root wrenching, and lifting date, are at least as important as irrigation or fertilization.

CONCLUSION

The attendee input gathered at the closing session was generally positive, with the major criticism being that more emphasis could have been given to interpretation of soil test results and on-the-ground problems.

Workshop proceedings will be available in early 1981, from Regional Offices of th Forest Service and from the State University of New York at Syracuse. I will be contacting all those on my mailing list as soon as they are received in my office.

It was agreed that these specialized workshops are valuable and should be held every 5-10 years. Shorter workshops could be held in conjunction with yearly nurserymen's meetings.

The State University of New York at Syracuse Soils Laboratory will continue processing nursery soil samples on a request basis. Forest Service sponsorship of soils testing will no longer be available because of funding restrictions.

We are currently working with soil scientists to develp a set of standardized techniques for nursery soil testing. Ideally, we will be able to request standard soil tests from local testing laboratories which will minimize turnaround time and encourage special treatment of local soil conditions. The most challenging problem will be to engage local soils experts to provide test data interpretation.

Soil is an essential but complicated phase of nursery soil management, but one that, I am sure you agree, deserves continued attention.

THE AMERICAN ASSOCIATION OF NURSERYMEN AND ITS GOVERNMENT NURSERY PRODUCTION COMMITTEE

Lee W. Hinds
Nurseries Manager
Lincoln-Oakes Nurseries
Bismarck and Oakes, North Dakota

The American Association of Nurserymen was organized in 1975, and has grown steadily as the national trade organization of the nursery/landscape industry. Today it serves about 3,000 member firms involved in the nursery business - wholesale growers, garden center retailers, landscape firms, mailorder nurserymen, and allied suppliers to the horticultural community.

The Association serves its members in many ways: national representation on Capitol Hill, in Federal agencies and departments; promotion of the industry and its products to the consumer through a variety of public relations and sales aids and materials, through national public service radio and television announcements, through regular press packages to the nation's top newspapers; management services in the form of valuable reference materials and regularly scheduled clinics and workshops; news, facts, opinions, forecasts distributed regularly to member firms in the form of biweekly and quarterly periodicals and at the annual convention and trade show; consulting services available to members at reduced cost in the areas of transportation, wage-hour regulations and the Occupational Safety and Health Act (OSHA); low-cost group insurance programs; a member bank card plan offering an attractively low discount rate to those firms which accept VISA and Master Charge credit cards.

The AAN has a distinguished history. The nation's first Secretary of Agriculture was a two-term president of the Association. The group is recognized as a pioneer in the highway beautification movement. It spearheaded the vital "Victory Garden" program during World War II. The AAN was responsible for instigating the existing commercial plant quarantine system.

Through its National Landscape Awards Program, the Association encourages active participation in community improvement by the business world. This program urges businesses, industrial, institutional and governmental organizations to improve the quality of their environment through landscape beautification. Over the years, the program has been chaired by prominent business and government leaders, including four First Ladies, and the presentation ceremony has occurred at the White House on five separate occasions.

The AAN encourages citizen action for environmental enhancement via its Green Survival Program which says that one person can take many small steps to protect and improve the quality of life in our land. Air, earth, water, sight, sound, energy, peace of mind, personal security - all depend in one way or another on green, growing trees and shrubs and grass and plants which are nature's gifts. The steps each citizen can take in using these gifts have come to be known by the name "Green Survival." The program, initiated in 1970, came into particular prominence in 1976 when it was recognized by the American Revolution Bicentennial Administration as an official Bicentennial activity.

Led by Robert F. Lederer, executive vice president, the staff of the AAN is also responsible for management of a group of "family" organizations. The Horticultural Research Institute is the non-profit research arm of the nursery industry; Wholesale Nursery Growers of America provide specific services for the wholesale grower; National Landscape Association serves the landscape community; Garden Centers of America counts among its members nursery retailers and garden center operators; National Association of Plant Patent Owners serves the specialized group of businesses which hold patents on plant materials.

In addition, the American Association of Nurserymen manages The Nursery Marketing Council, established in 1977 to supply the nursery industry with professional market research and analysis and the resulting advertising and public relations to increase the sale of plant materials and related products and services. NMC is funded solely by voluntary contributions. Its activities are performed for the benefit of the entire nursery industry and those businesses that serve to support and enhance nursery products.

The Wholesale Nursery Growers of America and the Horticulture Research Institute are two of the "Family Organization" that have a great deal in common with the forest and shelterbelt tree nursery production. Both are committed to less expensive ways of growing high quality plant material. It behooves us to seek cooperation at every opportunity.

The AAN has two kinds of committees, active and consultant. Active committees are those which meet periodically and develop programs within their area of responsibility or have continuing jobs to do. Consultant committees are a completely different story. Members of these committees have been selected because of their technical knowledge in a particular area of the business. They are not scheduled to meet on a regular basis, but are on tap when the chairman or staff needs counsel in a specific area.

One of the Active committees is the Government Nursery Production Committee. The primary function of this committee is to keep the government out of active participation in the nursery business, a task which requires constant vigilance.

Members of this committee include Steve McDonald of U.S. Forest Service; Robert MacLaughlin of the Soil Conservation Service; Robert Eastman of the Western Maine Forest Nursery Company; Esther Lawyer of Lawyer Nursery, Montana; Ted Korves, Plumfield Nurseries, Inc., Nebraska; and myself among others. This group does all in its power to dissuade the "government agency", at whatever level, from becoming involved in competition with private industry, whether this be Soil Districts, Municipal Entities, Experiment Stations, or State or Federal Nurseries.

All of us need to be on the alert that the private nurseryman receives every opportunity to provide the necessary plant material within his capability and at a quality acceptable for the use intended. The private sector should be assisted and encouraged at every opportunity.

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EVALUATION OF HERBICIDES FOR WEED CONTROL IN ROCKY MOUNTAIN-GREAT BASIN NURSERIES[1]

Russell A. Ryker[2]

ABSTRACT

We tested four herbicides (bifenox, DCPA, napropamide, and diphenamid) for effectiveness in reducing the handweeding time required for weed control in nursery seedbeds. Handweeding was reduced from 50 to 80 percent depending on herbicide and nursery. Tolerance of these herbicides by five species of pine, Engelmann and blue spruces, and Douglas-fir are summarized.

INTRODUCTION

The western nursery herbicide study is a broad-based study installed at many nurseries under a variety of conditions. The study objectives were to identify promising herbicides, develop data for product registration, and demonstrate safe and effective weed control practices for nursery seedbeds.

To conduct the study, the western United States was divided into three study areas: Pacific Coast, Rocky Mountain-Great Basin, and Great Plains. In each area a minimum of three years of work was planned. The first year was primarily a screening of 18 selected herbicides for weed control effectiveness, and tolerance by tree species. The second year, herbicides showing promise during first-year tests were tested further at different rates and time of application. Third-year tests were designed for assessing reduction in handweeding costs by each herbicide surviving the first two years of tests. For more detailed description see Ryker (1979). This report summarizes the results of third-year tests at the Rocky Mountain-Great Basin nurseries.

In addition to the planned third-year tests, at five of the nurseries we also screened oxyfluorfen (Goal 2E) for weed control and toxicity to several conifer and hardwood species. This was the first year we tested oxyfluorfen in Rocky Mountain-Great Basin nurseries.

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[1]Paper presented at the Western Forest Nursery Council and Intermountain Nurseryman's Association combined meeting, Boise, Idaho, August 12-14, 1980.

[2]Principal Silviculturist, USDA Forest Service, Intermountain Forest and Range Experiment Station, Boise, Idaho.

METHODS

Weed Control

The third-year weed control tests were installed at six nurseries:

Nursery	Location
Coeur d'Alene	Coeur d'Alene, Idaho
Lucky Peak	Boise, Idaho
Montana State	Missoula, Montana
Mountain Home	DeBorgia, Montana
Mt. Sopris	Carbondale, Colorado
Utah State	Salt Lake City, Utah

We tested four herbicides for weed control effectiveness: bifenox (Modown 80 WP), DCPA (Dacthal W-75), napropamide (Devrinol 50 WP), and diphenamid (Enide 50 WP). The treatments are described in table 1.

The post-seeding and post-seeding plus post-germination sprays were applied to 4-by 100-foot plots with three replications. Because most nurseries did not have sufficient bed space sown to one seed source or species, different replications were usually sown to different species.

The herbicides were applied in water at a volume equivalent to 50 gallons per acre using tractor-mounted nursery spray equipment adjusted to deliver a 4.5 foot swath. The plots were irrigated to move the herbicide into the soil soon after spraying was completed.

At each nursery all plots were handweeded when needed in the most weedy plot. Crew size, total weeding time per 100-foot plot, and weeding date were recorded each time. In every case the first weeding was done just before the post-germination spray was applied. For the remainder of the season there were one or more subsequent weedings depending on the nursery.

At three nurseries (Lucky Peak, Utah, and Mt. Sopris) we counted the number of individual weeds of each species on five sample plots per 100-foot plot. The sample plots were 20 x 50 centimeters and were systematically located in the middle of the bed at 0, 20, 40, 60 and 80 feet distances within each plot. The counts were made just before the first weeding on all plots. Because only the post-seeding sprays had been applied, they reflect only the effectiveness of the post-seeding treatments.

Phytotoxicity

The 1979 study was designed primarily to determine potential savings in handweeding costs at each of the nurseries, but we also collected data on phytotoxicity. At most nurseries each replication was sown to a different species, so we do not have the opportunity to test the data for statistical significance of toxic effects. However, the averages are good and would indicate any serious damage from the herbicides.

The phytotoxicity data were obtained from bed-width by 1-foot sample plots located at 20, 40, 60 and 80 feet from the start of each treatment plot. We estimated a damage rating using the system proposed by Anderson (1963). The system is a scale from 0 (all seedlings dead) to 10 (no damage). We also counted live seedlings in three randomly selected rows within each sample plot, excluding the outside rows. We lifted 10 seedlings from each sample plot and determined top length, top dry weight, and root dry weight.

Table 1.--Herbicide treatments tested for weed control effectiveness during the third year, 1980

Herbicide	Formulation	Rate	Time of application
		lb a.i./A	
Untreated	--	--	--
Bifenox	Modown 80WP	3	Post-seeding[1]
Bifenox		3+3	Post-seeding plus post-germination[2]
DCPA	Dacthal W-75	10.5	Post-seeding
DCPA		10.5+10.5	Post-seeding plus post-germination
Napropamide	Devrinol 50WP	1.5	Post-seeding
Napropamide		1.5+1.5	Post-seeding plus post-germination
Diphenamid	Enide 50WP	4	Post-seeding
Diphenamid		4+4	Post-seeding plus post-germination
Diphenamid plus bifenox		4 3	Post-seeding plus post-germination

[1]Abbreviated Ps in subsequent tables.

[2]Abbreviated Ps+Pg.

RESULTS

Handweeding Time

When data from all six nurseries were averaged, the total-season handweeding time was reduced more than 75 percent by bifenox treatments, about 60 percent by DCPA and napropamide, and about 50 percent by diphenamid.

Conditions varied greatly between some of the nurseries, particularly between nurseries that fumigated the seedbed ground and those that did not fumigate. The result was that some nurseries had very few weeds, irregularly distributed, and others had many weeds. Because of these differences, we computed separate statistical analyses for each nursery.

Statistical significance of total-season weeding times at each nursery are shown in table 2. You will notice in the table that the Modown treatments at Coeur d'Alene reduced handweeding time 85 to 90 percent, but the analysis of variance shows no significance at the 95 percent level. The difference, which is obviously real, is masked by the interaction between block and treatment. Block III had about 14 times more weeds than blocks I and II. Modown kept practically all the weeds out regardless of potential. Because there were very few weeds in blocks I and II, there was little difference between treatments in those blocks.

Table 2.--Effect[1] of herbicides on total-season handweeding time in the Rocky Mountain-Great Basin Nurseries, 1979.

Herbicide	Timing	Nursery					
		Montana	Mountain Home	Coeur d' Alene	Lucky Peak	Utah	Mt. Sopris
		Percent					
Untreated	--	100	100	100	100	100	100
Bifenox	Ps	53*	25*	15	50*	17*	7*
	Ps+Pg	23*	19*	10	36*	23*	5*
DCPA	Ps	--	45*	--	50*	32*	12*
	Ps+Pg	--	25*	--	35*	31*	12*
Napropamide	Ps	—	56*	--	63	30*	21*
	Ps+Pg	--	28*	--	92	37*	22*
Diphenamid + bifenox	Ps Pg	--	--	--	--	--	25*
Diphenamid	Ps	--	--	47	98	--	--
	Ps+Pg	--	--	46	81	--	23*

[1]Percent values shown were obtained by dividing the total-season weeding times for each treatment by the weeding time for untreated plots. The asterisk indicates that treatment mean is significantly different from the untreated mean at the 5 percent level of probability.

The weed species encountered in the sample plots at the Lucky Peak, Utah, and Mt. Sopris nurseries are listed in table 3, along with an indication of the relative degree of control by the four herbicides. Effectiveness was judged by comparing the number of seedlings per square foot on the treated and untreated plots. The data are limited and not conclusive, but may be used as an index to the relative effectiveness of the herbicides on the species encountered. For instance, bifenox was quite effective against all of these species except field bindweed, whitetop, knotweed, and some of the grasses. DCPA and napropamide were less effective against some of the other species, but effective against the grasses.

Phytotoxicity

Damage ratings, survival, height, and top and root dry weights were summarized for the five pines, two spruces, and Douglas-fir. Rather than present those rather large tables here I interpreted them in terms of the safety of the herbicide treatments for each species (table 4). All four herbicides appear safe to use on ponderosa pine, lodgepole pine, and Douglas-fir. Diphenamid, however, was the only one that did not damage Engelmann spruce. Bifenox appears safe for all the pine species tested and Douglas-fir, but not for the spruces.

Bifenox seemed to adversely affect ponderosa pine during seedling emergence at some nurseries. However, I have no measure of this and by the end of the growing season there was no significant effect on number of seedlings or seedling growth.

At the Coeur d'Alene nursery they found some of the damage[3] from dacthal reported by Pacific Coast nurseries the previous year (Callan 1979). It was limited to certain seed sources and did not occur in our plots.

[3]Personal communication with Cleve Chatterton, Assistant Nurseryman, Coeur d'Alene Nursery.

Table 3.--Relative effectiveness[1] of the four herbicides on the major weed species.

Species	Bifenox	DCPA	Napropamide	Diphenamid
Clover	+	-	-	-
Common mallow	+	-	-	*
Dandelion	+	+	+	+
Field bindweed	-	-	-	*
Filaree	+	+	-	-
Grass spp.	-	+	+	+
Jerusalem oak	+	+	+	-
Knotweed	-	-	-	-
Kochia	+	+	-	*
Lambsquarter	+	+	-	-
Mint spp.	+	+	-	-
Nightshade	+	+	-	*
Prickly lettuce	+	+	+	*
Prostrate pigweed	+	+	-	-
Purslane	+	+	+	+
Redroot pigweed	+	+	+	+
Russian thistle	+	-	-	*
Shepherdspurse	+	-	-	+
Sunflower	+	+	-	*
Tansy mustard	+	-	-	*
Thistle spp.	+	+	+	*
Whitetop	-	-	+	*

[1]A "+" indicates the herbicide was effective against that species. A "-" indicates the herbicide was less effective. An * indicates the herbicide was not tested at the nurseries where this species appeared in the plot measurements.

able 4.--Relative safety[1] of the four herbicides tested in 1979 on eight conifer species.

pecies	Bifenox		DCPA		Napropamide		Diphenamid	
	Ps	Ps+Pg	Ps	Ps+Pg	Ps	Ps+Pg	Ps	Ps+Pg
onderosa pine	X	X	X	X	X	X	X	X
odgepole pine	X	X	X	X	X	X	X	X
ustrian pine	X	X	X	X	No	No	-	-
ugo pine	X	X	?	?	?	?	-	-
cotch pine	X	X	X	X	?	?	-	-
ouglas-fir	X	X	X	X	X	X	X	X
ngelmann spruce	No	No	No	No	?	?	X	X
lue spruce	?	?	No	No	No	No	-	-

[1] X--indicates those treatments that have been consistently safe to use in ur study plots. No -- indicates treatments that have been too damaging. ? -- esults uncertain or varied between nurseries. The dashed line indicates treatents not tested against that species.

OXYFLUORFEN PHYTOTOXICITY

In addition to the planned third-year study on the large plots, we installed some phytotoxicity tests of oxyfluorfen at five nurseries (Coeur d'Alene, Idaho, ucky Peak, Utah, and Mt. Sopris). We tested it on four species of conifers and hree species of hardwoods.

No weed control data were collected but observations indicated almost complete eed control until about midsummer by the post-seeding treatment. Total season weed ontrol appeared to be as good or better than with bifenox. If safe to use, this should be a very important herbicide for nursery weed control.

Number of seedlings and height growth of Douglas-fir and ponderosa pine were not significantly affected by oxyfluorfen. Lodgepole pine was not damaged at Lucky Peak ursery, but at Mt. Sopris the number of seedlings was reduced about 60 percent and eight growth reduced about 25 percent. The reason for the difference between urseries is not known. The effects on Engelmann spruce were highly variable within each nursery. The 2X rate was particularly damaging. All three hardwood species (Russian olive, willow, and squawbush) benefitted from the reduction in competition on treated plots.

Oxyfluorfen (Goal 2E) is now registered (EPA Reg. No. 707-145-AA) for use in conifer seedbeds. Lodgepole pine is included in the species list as is Colorado blue spruce. Our results in last year's tests indicate further phytotoxicity tests should be conducted at each nursery contemplating using this herbicide. This is particularly true for nurseries growing lodgepole pine and the spruces. The effectiveness of this herbicide for controlling weeds fully justifies further testing.

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THE WESTERN FOREST TREE SEED COUNCIL[1/]

D.G.W. Edwards [2/]

The Western Forest Tree Seed Council is a member council of the Western Reforestation Coordinating Committee of the Western Forestry and Conservation Association. It is organized to solve problems concerning tree seeds among organizations and individuals in the eleven Western States and British Columbia, and represents western forestry interests in matters of tree seeds. The Council Charter, adopted in 1965, allows that any person actively engaged in tree seed matters shall be a member in good standing with full privileges. Members meet periodically to discuss problems of common interest, to exchange scientific information and to undertake cooperative projects that will enhance reforestation practices.

The Council came into being as the Northwest Forest Tree Seed Committee in 1953 in Corvallis, Oregon. A name change to the Western Forest Tree Seed Council reflected its affiliation with the Western Forestry and Conservation Association and its geographic scope encompassing the western United States and Canada. While its objectives have broadened over the past 27 years, the Council continues to actively encourage, promote and participate in seed studies and the reporting of seed research. Space for an annual Seed Council report is provided in the proceedings of the Western Reforestation Coordinating Committee. The Committee and the parent Association serve as forums in which the Council can air important seed concerns before larger audiences. The Association has adopted several resolutions from the Seed Council and has also provided much needed assistance in reproducing and distributing several Council publications.

The Council executive comprises four officers elected every second year. Meetings are held at least once a year, more frequently if the need arises, and written minutes are circulated. As with many other organizations, the interest in and activities of the Western Forest Tree Seed Council have been difficult to sustain at certain times. During the early and mid-1960s, considerable activity centered around amendments to the Federal Seed Act, the development of seed zone maps and a seed certifying agency, to mention only a few. In 1975-76, a proposal surfaced to place the Council in an inactive status, since no critical seed issues were recognized at that time. However, the Council has rebounded vigorously in the last 4 or 5 years, due to the leadership of Ed Hardin of the Oregon State Seed Laboratory.

A series of committees concerned with seed standards, certification, legislation, seed zones, research, referee testing and other matters have carried forward most of the Council's activities. The early achievements have been

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[1/] Paper presented at Joint Meeting of Intermountain Nurseryman's Association and Western Forest Nursery Council, Boise, Idaho, Aug. 1980.

[2/] Chairman, Western Forestry Tree Seed Council. Mailing address: Canadian Forestry Service, Pacific Forest Research Centre, Victoria, British Columbia.

documented by Stein (1974)[1], so only a brief synopsis is necessary here.

i) The 1966 Seed Zone Map for Oregon and Washington. Revised in 1975, allowing zones to mesh with those in adjacent states and British Columbia.

ii) Establishment of the Northwest Forest Tree Seed Certifiers Association, also in 1966.

iii) In the late 1960s, the development of a Model State Seed Law for forest tree seeds.

iv) Publication of a booklet on tree seed testing techniques, first issued in 1959. The Council's testing methods for tree seeds were adopted by the Association of Official Seed Analysts in 1965, and an updated booklet on tree seed sampling and testing was published in 1966.

v) Secured funds for a study on germination in Abies species, the results of which were published in two reports by the Oregon State Seed Testing Laboratory.

vi) Continued to press for additional research on western forest tree seeds, culminating in a proposed seed research program aimed primarily at (a) improving seed processing, (b) better seed testing, and (c) improved seed use. The proposed program was to be conducted at a federally funded laboratory in Corvallis.

Since 1976, the Council has persisted in emphasizing seed research needs. The Seed Research Committee met with the Director and Assistant Director (South) of the Pacific Northwest Forest and Range Experiment Station to explore the development of the much needed cone and seed research program. Although space and equipment have been allocated in the Corvallis station, completed in 1977, no work has been initiated.

Despite the compilation of a list of tree seed research requirements that identified more than 20 problem areas, such work retains low priority in the PNW Station's plans, since funding is still a major stumbling block. As something of a palliative, the Council has encouraged and promoted active participation in its meetings of seed researchers employed by private industry, university and other government agencies. In the last 3 years, a considerable amount of tree seed research has been reported to the Council by representatives from Weyerhaeuser Company, Washington State and Oregon State Universities, the British Columbia Ministry of Forests and the Canadian Forestry Service, and others. This work is the result of individual programs at each Centre and remains uncoordinated. Many of the problems identified by seed workers in the Pacific Northwest remain unresolved and the Western Forest Tree Seed Council must redouble its efforts of pressuring for funds if new seed programs are to be undertaken.

Other activities in recent years include:

vii) Referee testing of Douglas-fir and Abies species. Two 2-day workshops were

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[1] Stein, W.I. 1974. Activities of the Western Forest Tree Seed Council. Proc. Western For. Nurs. Council, Portland : 3-7.

also promoted by the Council and held in the facilities of the Oregon State Seed Testing Laboratory. Each workshop attracted some 30 participants who studied purity and germination testing, and the so-called quick tests (tetrazolium, excised embryo, hydrogen peroxide and x-ray). Emphasis was on uniformity of testing through the use of procedures described in the AOSA Rules.

viii) A long-term seed storage project at the National Seed Storage Laboratory, Fort Collins, Colorado, that now includes several tree species.

ix) Compilation of a list of tree seed research requirements. The list, identifying 23 problem areas, was widely distributed.

x) A half-day symposium on Seed Vigor was held during the 1979 meeting. Participants had the components of seed vigor and the testing of seed vigor explained by staff members of Oregon State University.

xi) The last three annual meetings have seen detailed accounts of research on revegetation of disturbed lands; true fir seed maturity, cone and seed insect control, cone collection and after-ripening, grading and sorting; air drying of stratified seeds of ponderosa pine and Douglas-fir to improve germination; quick tests to replace standard germination tests, and drying and storing stratified true fir seeds.

The Council is working toward revising and re-issuing the booklet on "Sampling and Service Testing Western Conifer Seeds" and is considering the preparation of a publication on quick tests. Other seed testing workshops have also been proposed.

Peripheral supporting actions continue, as ongoing events and as new developments, but the Council's major concern is the lack of implementation of its seed research program. As nurserymen, you are as vitally concerned with tree seeds as anyone, and your support of the Western Forest Tree Seed Council is highly valued. On behalf of the Council, I invite your participation in all our activities, and especially welcome your support on problems of mutual concern.

AN INTRODUCTION TO THE WESTFIR TRANSPLANT NURSERY [1/]

Rodney F. Matye [2/]

Approximately 40 miles southeast of Eugene, Oregon, along the Willamette Pass Highway, lies the small community of Westfir. Here, at the foothills of the Cascade Range, is where the Westfir Transplant Nursery is situated.

The Nursery was established in 1960 by the Willamette National Forest to: "provide a large vigorous seedling which could be lifted and planted to the field in a very short time". The Nursery lies on alluvial terraces of the Middle Fork of the Willamette River at an elevation of 1,020 feet. The annual precipitation rate is 42 inches of rainfall and the mean average temperature is 53 degrees Fahrenheit.

In proposing the establishment of Westfir, the Forest contemplated the production of transplant stock solely for those sites most difficult to reforest. Furthermore, the Forest recommended the transplant operation be discontinued when stock of equal quality but lower cost became available.

We have come a long way since those Forest recommendations were made. Outplanting of Westfir stock began in the fall of 1960. In December of 1961, the nursery was enlarged to 6 acres, with a projected capacity of 1.4 million seedlings. Trees being lifted, in those days, had to transported to the Flat Creek Work Center for processing, a distance of 10 miles. The equipment for nursery work came from surplus property lists, except for the tractors, those were rented from local farmers.

The efficient and economical operation of the nursery required additional bed space, equipment storage facilities, the acquisition of additional equipment, the construction of a processing room and a cold storage facility. The process of getting approval and budgeting for these improvements came over a span of six years.

Since 1976, additional improvements have been made at the Nursery. We identified soil problems arising from extended use of Simazine and Atrazine as well as some poor cultural practices. Through close cooperation with the Forest soil scientist and other personnel, a soil management plan was developed and activated.

In 1978, a new office and an additional tree storage facility were under construction. These are completed now and provide a pleasant atmosphere for the 50 employees the facility employs during its operating season.

Today we have 17 acres available for transplant seedlings. We try to put 4-5 acres a year into a cover crop of annual rye grass.

1/ Paper presented at Joint Meeting of Western Forest Nursery Council and the Intermountain Nurseryman's Association, Boise, Idaho, August 12-14, 1980.
2/ Nurserymanager, Westfir Transplant Nursery, U.S.D.A. Forest Service, Oakridge, Oregon 97492.

A serious drainage problem, which caused mortality and chlorotic trees, was reduced and in some cases eliminated by installing 7 miles of perforated drainage pipe. The installation of this pipe, with laser equipment, to maintain depth and slope specifications, was a real learning experience in itself.

Irrigation efficiency was increased with the installation of a new pump and mainline assembly. Our water is pumped directly from the river by a submersible Jacuzzi 7½ horsepower pump. A 6 inch mainline feeds the 2 inch laterals where 55 psi head pressure is maintained for uniform coverage.

As is the case at most nurseries, Westfir has a weed problem. An aggressive weed control program which includes fumigation, as well as the utilization of herbicides and hand weeders, helps keep the situation manageable.

The Nursery utilizes two International tractors for heavy cultivation work and a small International for light cultivation.

A Mann-Fleming tree lifter, with spare shaft, is used for lifting. Our transplanting is accomplished by using a New-Holland Model #500 six row transplanter. We have found this model easy to adjust and it can be operated at a fairly good rate of speed.

The Nursery last year provided services to four National Forests and the Bureau of Land Management. We produced 1.9 million transplants at a cost of $190/M.

The Nursery has generally been transplanting bare-root 2-0 seedlings grown from the Wind River, Medford and Humbolt Nurseries. We have noticed an increased request for transplanting 1-0 bare-root seedlings as well as some containerized stock.

This year as in the past few years we regretfully turned away potential customers because we had already filled all available bed space. Even though - there is talk of a new nursery in the Willamette Valley, I believe Westfir, as well as other transplant nurseries, can expect a very productive future.

ECTOMYCORRHIZAE: PRESENT STATUS AND PRACTICAL APPLICATION IN FOREST TREE NURSERIES AND FIELD PLANTINGS[1]

Charles E. Cordell and Donald H. Marx[2]

ABSTRACT

Increased growth and quality have occurred in test lots of seedlings at bareroot and containerized seedling nurseries that participated in trials of practical applications of selected ectomycorrhizal fungi. Increased tree survival and growth also occurred in related field plantings on a wide variety of conifer species and planting sites. Several alternative methods are presented concerning the practical inocualtion of nursery seedbeds with ectomycorrhizal fungus inoculum.

Additional key words: *Pisolithus tinctorius*, ectomycorrhizal inoculum, conifer host species, seedling growth and quality, tree survival and growth, bareroot nurseries, container nurseries, ectomycorrhizal inoculation techniques.

INTRODUCTION

During the past several years, researchers at the Institute for Mycorrhizal Research and Development (IMRD), Athens, Ga., and pest management specialists, Atlanta, Ga., both with the USDA Forest Service, have been conducting extensive mycorrhizal research and field application studies with several forestry agencies. This work has centered around one ectomycorrhizal fungus, *Pisolithus tinctorius* (*P.t.*), and its practical application to forest tree nurseries and field forestation.

Since 1977, a national evaluation has been in progress to test the effectiveness of different formulations of *P.t.* inoculum produced by Abbott Laboratories, Chicago, Ill., and the IMRD on selected conifer seedling species. A progress report on this evaluation was presented at the Western and Intermountain Nurseryman's Conference, Snowmass, Colo., August, 1979 (Cordell and Marx, 1979).

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[1] Paper presented by senior author at the Western and Intermountain Nurserymen's Conference, Boise, Idaho, August 11-15, 1980.

[2] National Coordinator, National Mycorrhizae Nursery Evaluation, Forest Pest Mgt., Southeastern Area, USDA Forest Service, Asheville, N.C., and Direstor, Institute for Mycorrhizal Research and Development, Southeastern Forest Experiment Station, USDA Forest Service, Athens, Ga., respectively.

During the past 3 years, over 80 bareroot nursery tests have been conducted in some 38 states. Eighteen companion container nursery seedling evaluations have also been conducted in nine states (including Hawaii) and Canada. The objective of these evaluations was to compare the effectiveness of P.t. inocula produced by the IMRD and Abbott Laboratories for P.t. ectomycorrhizal formation, seedling growth and quality in the nursery, and tree survival and growth in subsequent field outplantings. Results obtained from these field studies continue to be encouraging and suggest that P.t. may have practical application for a variety of conifer and some hardwood seedling species produced in bareroot and container nurseries.

PRESENT STATUS OF *P. TINCTORIUS* ECTOMYCORRHIZIE

Bareroot and Container Nurseries

Research and nursery field evaluation results continue to demonstrate that P.t. can be successfully, artificially inoculated into prefumigated nursery seedbeds(fig. 1) (Marx, et. al., 1976, Marx and Artman, 1978) and container mixes (Ruehle and Marx, 1977). Successful seedbed inoculations have been obtained in a variety of nurseries with various conifer species and some hardwoods (oaks). Positive bareroot nursery seedling benefits involving significant increases and decreases in seedling fresh weight and cull percentages respectively, have been observed in several nurseries, (Cordell and Marx, 1979). Thus far, the P.t. inoculum produced by the IMRD has been more effective and consistent than the Abbott P.t. inoculum in the formation of P.t. ectomycorrhizae and effect on seedling growth and quality. Some Abbott P.t. inoculum batches, however, have been highly effective. Research in 1980 by the IMRD and Abbott Laboratories is aimed at rectifying these formulation problems.

Figure 1.--*Pisolithus tinctorius*

Results obtained from the 1978 container seedling studies with both the IMRD and Abbott P.t. inocula were highly encouraging (Cordell and Marx, 1980). The IMRD P.t. inoculum produced an average of 40 percent P.t.ectomycorrhizae on seedling feeder roots. The Abbott P.t.inoculum produced an average of 20 percent P.t. ectomycorrhizae and both inoculum sources produced some P.t. ectomycorrhizae on 100 percent of the seedlings inoculated. Note that these positive results were obtained on 12 conifer and one hardwood (burr oak) species in seven States (Maine to Georgia to Oregon) along with Ontario, Canada.

Field Plantings

A number of outplanting tests were made on a variety of forestation sites--routine, coal spoil, kaolin wastes, etc. -- in scattered locations in the United States before the national IMRD-Abbott inoculum evaluation (Berry and Marx, 1978; Cordell and Marx, 1977; Marx, et al., 1977). Significant increases in tree survival and growth (25+%) have been obtained on some sites after 6 years in the field. Field forestation benefits have been consistently higher on the poorer quality planting sites. Initial outplantings with the Abbott P.t. were established during the Spring of 1979. To date, over 20 outplantings have been established involving a variety of conifer species and planting sites across the United States. The outplantings are scheduled for a 10-year duration, with annual tree measurements and progress reports.

P.t. Inoculum Availability

Abbott Laboratories developed techniques and procedures for the commercial production of P.t. mycelium-vermiculite-peat inoculum. During the past 3 years, this firm and IMRD have been conducting extensive cooperative research and field evaluation studies of the commercial production of P.t. fermentor inoculum for practical application in forest tree nurseries.

The future commercial production of P.t. inoculum by Abbott Laboratories, or an alternate producer, will depend, primarily, on the consumer demand (forest tree nurseries) and the prevailing economy. Presently, the indicated nursery demand for P.t. inoculum and prevailing economical conditions are not highly favorable for the commercial production of this product. Any commercial P.t. production by Abbott Laboratories in the next few years will most likely be based on special agreements and custom P.t. inoculum orders between various nurseries and the company.

Several alternative P.t. inoculum producers, types and practical nursery inoculation techniques are being investigated by the USDA Forest Service. The most promising inoculum types and seedbed inoculation techniques are described in the following section.

PRACTICAL APPLICATION OF *P. TINCTORIUS* IN BAREROOT AND CONTAINER NURSERIES

The most practical and effective means of using P.t. is by inoculating either bareroot nursery seedbeds or containers before seeding. Best results have also been obtained following effective methyl bromide soil fumigation of the nursery seedbeds. Seedling container mixes can be easily and effectively treated with the inoculum before seeding (Ruehle and Marx, 1977).

The following possible alternatives are available for consideration with P.t. inoculations in bareroot nurseries:

1. Commercial inoculum broadcast on seedbed surface with fertilizer spreader equipment and rototilled in with a bed shaper before seeding. This method is simple and does not require special equipment. However, it requires a larger, much more expensive volume of P.t. inoculum

2. P.t. spores mixed with hydromulch and applied to nursery seedbeds immediately after seeding. This method has primary advangages similar to 1, above, other than the need for a hydromulcher. However, there are several disadvantages to this inoculation method. First, a large volume of P.t. spores is required. Second, the spore germination lag time gives a competitive advantage to other soil fungi. Results to date have shown the P.t. spore inoculum to be less effective than laboratory-grown P.t. inoculum (mycelium without spores) in nursery seedbeds. However, results obtained from a P.t. spore hydromulch inoculation study in Oklahoma were very effective (Marx, et al., 1979).

3. P.t. spore encapsulated seed treatments. Although still under study, preliminary results have been very promising. The advantages and disadvantages of this method are similar to other P.t. spore inoculation methods. In cooperation with the IMRD, the International Tree Seed Company, Birmingham, Ala., is developing plans and techniques for the production of P.t. spore-encapsulated seed for a variety of conifers.

4. Commercial inoculum applied in nursery seedbed drill rows with an ectomycorrhizal inoculum applicator-tree seeder. During 1979, a nursery seed planter was modified by the USDA Forest Service for the simultaneous application of P.t. inoculum and seedbed sowing in nursery seedbeds (fig. 2). The ectomycorrhizal inoculum applicator-tree seeder is being tested in four southern nurseries during 1980. If effective in promoting P.t. development on seedling feeder roots, such a machine should be highly useful in forest tree nurseries. A major advantage of this seedbed row-drilled technique would be a much lower volume for P.t. inoculum (67 percent less than seedbed broadcast method) as well as substantial savings in time, labor, and other costs. The additional machine requirement is a primary disadvantage. However, most existing nursery seeders could be modified, at relatively minimal cost, to apply the inoculum.

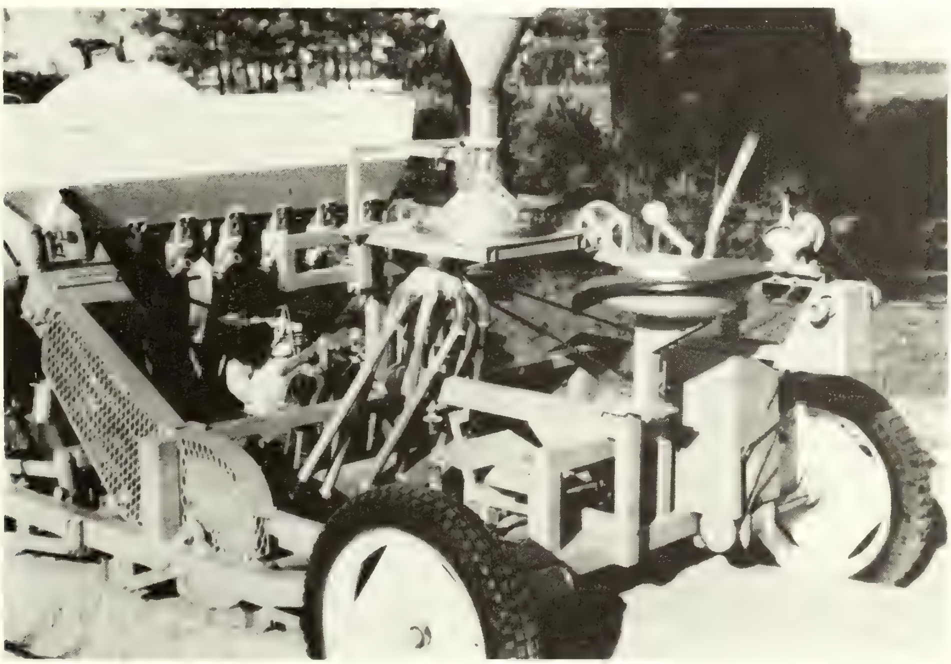

Figure 2.--Inoculum applicator-tree seeder

SUMMARY AND CONCLUSIONS

1. Certain ectomycorrhizal fungi, such as P.t., can be successfully artificially inoculated into container seedling mixes and bareroot seedbeds with both mycelium and spore inoculum.

2. The P.t. mycelium inoculum, however, has been superior to the spore inoculum.

3. P.t. has a very broad seedling host and geographic range across the United States and around the world. Other ectomycorrhizal fungi may act similarly.

4. Positive seedbed and container inoculation benefits involving seedling growth and quality in the nursery along with increased tree survival and growth in field plantings have been repeatedly demonstrated.

5. Several potential practical P.t. inoculum application techniques, using either mycelium or spore inoculum, in container and bareroot nurseries are available for consideration by the nurseryman.

6. A variety of additional ectomycorrhizal fungi (i.e., Thelephora, terrestris, Rhizopogon, Laccaria, etc, may be more effective and practical for nursery application than P.t. in specific locations in the United States (i.e., Pacific Northwest). However, the same application techniques previously described can be modified for use with other ectomycorrhizal fungi.

7. The application of ectomycorrhizae to nursery seedling production is another "tool" for use in the quest for increased quality seedling production. Therefore, we challenge all nurserymen to become fully aware of the potential benefits and practical application of ectomycorrhizae in quality seedling production. This will enable the nurseryman to properly evaluate this "tool" for nursery use the same as for other high-quality products.

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ROOT MORPHOLOGY CONTROL IN FOREST TREE SEEDLING CONTAINERS[1]

S. E. McDonald, R. W. Tinus, and C.P.P. Reid[2]

ABSTRACT

Controlling seedling root morphogenesis in containers with chemicals can result in seedlings which rapidly establish natural root systems following outplanting. Copper and synthetic auxin compounds placed on the interior walls of containers reversibly stop root growth at the container wall. This has resulted in an adventitious proliferation of root tips up and down the root plug cylinder. These tips grow radially outward from the plug when the trees are planted so that many growing points penetrate the soil at various soil depths. As a result, trees should become rapidly established, be better anchored, and grow faster.

INTRODUCTION

Tree seedlings grown in forest tree containers frequently become stunted or die several years following outplanting (Hellum 1978). Sometimes they become prone to windthrow (Chavasse 1978). These and other problems with tree growth following outplanting often occur not only with container seedlings, but also with bare-root trees (Van Eerden and Kinghorn 1978). Root system deformities are thought to be the prime cause. These deformities seem to fall into two categories for containerized stock:

1. Root tips are concentrated in the bottom of the planting hole and grow into the soil only at the bottom of the hole following outplanting.
2. Roots penetrate the soil only to a limited extent following outplanting, and form an increasingly compacted mass in the original root plug area.

Is there a way to grow trees at the nursery to prevent these field problems?

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1. Paper presented at the Joint Meeting of the Intermountain Nurserymen's Association and Western Forest Nursery Council, Boise, Idaho, August 12-14, 1980.

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In 1978, Dr. A. N. Burdett (1978) of the BCFS Research Division, Victoria, Canada, reported that copper carbonate in acrylic latex paint applied to container walls would reversibly stop root growth at the wall. This was done by mixing a small amount of copper carbonate (30 to 100 g/l) with acrylic latex paint and painting the inside of the container with the mixture before growing the trees in it. When their tips reached the wall of the containers, many of the lateral roots of the seedlings stopped growing instead of turning and continuing to grow down the walls to the root egress hole. The laterals that stopped often developed a series of adventitious roots. These roots also stopped growth at wall contact. The result was a series of root tips at the container wall. Upon removal from the container, these root tips resumed growth outward from the sides of the root "plug." This lateral root growth promised better lateral anchorage and access to water and nutrients and suggested such root morphogenesis control could be a feasible operational procedure. Accordingly, a cooperative research effort between the U.S. Forest Service and Colorado State University was started to validate Burdett's work and extend knowledge about the technique.

PROJECT DESCRIPTION

The goal was to control seedling root development in nursery containers so root growth following outplanting would take place rapidly and in a more or less natural pattern. Factors to be manipulated were (1) root density in the container, (2) mechanical configuration of the container, and (3) chemical applications to the interior walls of the containers. The first stage, being reported on here, sought to (1) corroborate Burdett's work, (2) evaluate the possibility of using other root growth inhibitors the same way, and (3) to check the effects of these inhibitors over a range of concentrations.

MATERIALS AND METHODS

Spencer-Lemaire 30 cu. in. bookplanters[R] were used in the rate spectrum test. When laid out flat the interior of this type of container is easily painted with a brush. Three chemicals were mixed with the paint:

1. copper carbonate ($CuCO_3$).
2. indole-3-butyric acid (IBA), a synthetic auxin which has been shown to inhibit root growth in many plants at concentrations in excess of 10^{-7} to 10^{-13}M (Salisbury and Ross 1978).
3. trifluralin herbicide (Eli Lilly's Treflan EC) which inhibits root growth (Nussbaum 1969).

These chemicals were used in the following treatments:

Additive	White Paint[1]	Black Paint[1]
None	No paint	No paint
None	Paint only	Paint only
Copper	100 g/l	-[2]
Copper	10 g/l	-
Copper	3 g/l	-
Copper	1 g/l	-
IBA	50.0 g/l	50.0 g/l
	5.0 g/l	5.0 g/l
	0.5 g/l[3]	0.5 g/l
	0.05 g/l	0.05 g/l
	0.005 g/l	0.005 g/l
	0.0005 g/l	0.0005 g/l
Treflan	70.88 g/l[4]	70.88 g/l
Treflan	14.18 g/l	14.18 g/l
Treflan	2.84 g/l	2.84 g/l
Treflan	0.56 g/l	0.56 g/l

1/ Because IBA and Treflan degrade in light and paint pigment differences may affect results, two colors were employed.

2/ Only a white paint treatment was used, since $CuCO_3$ is not affected by light.

3/ Approximately 10^{-2}M.

4/ The recommended herbicide dose for silt soils (grams per liter of spray solution) would equal about .12 cc per liter of solution.

The solutions in the tabulation were applied to the inside of the containers, the paint allowed to dry, and the containers filled with growing medium. Ponderosa pine (Pinus ponderosa LAWS.) seeds were placed in the cavities and covered with a thin layer of perlite. There were three replications of four cavities (three books) for each treatment. The replications were randomly placed in wire container rocks and put into a greenhouse for germination and growth. Seeding and culture of the seedlings followed directions in Tinus and McDonald (1979).

When the seedlings were judged to be of plantable size and had enough root development to provide a cohesive root plug, the trees were removed from the containers Half were transplanted to a greenhouse bench filled with moist vermiculite for continued growth. The growing medium was gently removed from the roots of the other half. Shoot height, number of needles, needle length, dry weight shoot, dry weight root, the number of roots deflected downward at the wall, and the number of roots reaching the egress hole were measured or counted.

RESULTS

The principle results of this work were:

1. Treflan had a deleterious effect on seedlings at all concentrations. It was dropped.
2. There was little difference between trees grown in black versus white containers.
3. At 100 g/1, copper carbonate was effective in limiting root downturn at the wall as shown below:

$CuCO_3$ Concentration (g/1)	Root Deflected	Roots at Egress Hole
0	12.2	21.5
1	7.5	18.5
3	9.0	20.3
10	9.7	21.5
100	3.7	13.2

In addition, the copper carbonate appeared to stimulate growth as the concentration increased:

$CuCO_3$ Concentration (g/1)	Height(cm)	Dry Weight Shoot (g)	Dry Weight Root (g)
0	44.2	0.48	0.35
1	48.7	0.60	0.39
3	54.8	0.92	0.54
10	54.8	0.81	0.48
100	65.2	1.00	0.61

4. At 50 g/1 the IBA effect was similar to $CuCO_3$, but not quite so strong. At lower concentrations there was some growth stimulation.
5. After removal of the seedlings from the containers, the IBA and $CuCO_3$ coatings were still in very good condition and could probably have been used several times more.

The other half of the trees, previously removed from their containers and planted in moist vermiculite, were grown for about five weeks (11/29/79-1/9/80). They were then removed from the growing medium and the total length of each new side or bottom root was measured. The length of side roots as a percentage of total root length was calculated as shown below:

$CuCO_3$ Treatment (g/1)	Side Roots as Percent of Total Roots
0	7.8
1	4.7
3	12.1
10	12.0
100	27.1

IBA Treatment (g/1)	Side Roots as Percent of Total Roots
0	9.4
0.0005	13.3
0.005	5.2
0.05	12.9
0.5	11.7
5.0	18.9
50.0	34.3

DISCUSSION

The prime variable not addressed in the work reported here is root density in the container, a function of growing time. Root crowding in the container may strongly affect how roots develop after trees are outplanted. Work currently underway addresses this question by comparing $CuCO_3$ and IBA wall coatings and lateral root egress holes with various degrees of root development of ponderosa pine. We hope to determine a container treatment - degree of root development combination that will allow seedlings to develop a natural, or better than natural, root system. Other work in progress includes:

1. Finding the actual concentration of copper and IBA ions which cause the root growth inhibition at the container wall.
2. Developing methods for quickly screening a variety of other ions and ion concentrations for temporary root inhibition. The object is to find cheaper, possibly more effective, chemicals to use.
3. Perhaps there will be higher mycorrhizal infection rates in chemically treated seedlings. This should follow, since there are more root tip growing points for mycorrhizal fungi to inhabit. Tests are being conducted with Pisolithus tinctoriu and Suillus granulatus fungi (in cooperation with S. Grossnickle, College of Forestry, Colorado State University).

SUMMARY

There is potential for development of container seedlings that will have root tips, pointing outward and ready to grow, all over the surface of the root plug. Upon planting, the rapid extension of these roots into surrounding soil could very quickly produce a root system as good as, or better than the root system of a tree seeded in place. Roots would grow into the upper soil layers for good lateral force resistance and absorbtion of nutrients as well as downward. Such trees would be healthier, become fully established faster, and be less prone to windthrow in later life. Much more research needs to be done, but initial results are very encouraging.

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QUALITY CONE COLLECTION[1/]

Alfred Borchert[2/]

ABSTRACT

Good forest management depends on the fast reforestation of logged areas with the right species of seedlings that are vigorous and healthy and from the proper area of location. To produce vigorous healthy seed and seedlings, proper quality cone collection and handling is a must. To accomplish quality cone collection, a lot of technical and biological know-how, as well as "Common Sense" must be exercised. To accomplish the job, proper planning and good existing seed bank records are needed.

INTRODUCTION

This presentation will focus on the collection of cones from Douglas-fir, since we have had very little experience collecting cones from other species. However, most basic principles and common sense will apply to any other species. The harvest of cones is the same as the harvest of other farm or orchard crops. Since the seed from cones generally is not consumed as food, but to produce seedlings, seed source and identity maintenance becomes highly important.

Most conifer forest tree species produce cones at irregular intervals. Douglas-fir produces cones at 3 to 5 year intervals and good heavy crops occur at about 7 year intervals. The quality of seed is low and the cost to produce seed is high during low and medium cone years, whereas just the opposite is true during years when cone production is high. At the same time, seed is being used up every year for reforestation. Proper seed bank inventories and planning cone harvests accordingly is critical.

PLANNING TO COLLECT CONES

The first step is to determine from the seed bank inventories what species need to be collected, from what areas and elevations, and how much seed is needed in each seed lot to replenish the seed bank. This should be updated annually, regardless whether a cone crop is on its way or not. It is also a good idea to identify those seed lots in which seed needs have become critical, so that they will be high priority in case of budget cuts or if a poor cone crop exists and collection is much more expensive.

1/ Paper presented at the Intermountain Nurseryman's Association and Western Forest Nursery Council joint meeting, Boise, Idaho, U.S.A., August 11 - 14, 1980.

2/ Author is Assistant Seed Orchard Manager at the Walter H. Horning Tree Seed Orchard, B.L.M., Colton, Oregon.

The next step is to inventory those collection areas in which cones need to be collected. A potential cone crop can be determined when reproductive buds have developed. A good time for Douglas-fir is April and May. During these 2 months reproductive buds have well developed or are open, depending on elevation and they are easily recognized, even on large trees, with binoculars. It is also possible at this time to identify the potential crop as light, medium or heavy. A general rule for Douglas-fir is that if cones are present only in the upper 1/3 of the crown, it is considered to be a light crop, if they are present in the upper 1/2 of the crown it is considered a medium crop and if cones are found in all parts of the crown it could be a potential heavy crop. To do this inventory it is important that one becomes thoroughly familiar with the "Reproductive Cycle" of each species inventoried.

Based on the inventory a collection plan must be developed that contains at least the following items:

1. Labor needs.
2. Equipment needs.
3. Transportation needs.
4. Prices and costs.
5. Collection methods.
6. Training.
7. Buying stations.
8. Seed extraction contracts.

The final determination for a collectable cone crop must be made as close to collection time as feasable by determining seed set and quality in the cones. This is evaluated by the cut test. The cone is sliced in half and the cut embryos are counted on one side. On Douglas-fir 5 cut embryos is considered to be a medium crop and 7 a heavy crop. After this test has been done for all collection areas the final selection of collection areas, the collection sequence, and priorities must be established.

CONE COLLECTION AND HANDLING

Collect cones as close to maturity as possible. This sometimes is difficult to do because of timing, or economic reasons. If this is the case, cones can be picked somewhat premature and through various methods, after-ripened, depending upon species. Maturity of cones must be determined prior to collection, and some of the following symptoms can be used:

1. Overall color of cones.
2. Color of scales or bracts.
3. Size of seed.
4. Color of cut endosperm.
5. Size of embryo.
6. Separation of seed from bracts.

Again symptoms change with species, and the "Reproductive Cycle" of the species to be collected must be fully understood.

The following methods can be used to collect cones:

1. Standing trees.
    a. Climbing and hand picking.
    b. Ladders and hand picking (also power ladders and man lifts).
    c. Mechanical shakers.
2. Felled trees.
3. Topping of trees.

4. Squirrel caches.

The size, location, value and species of the tree determines what method to use. Sometimes economic reasons will also influence the type of method used.

The cone is a living organism, and handling of that organism during and after collection is very critical in order to produce top quality seed. Rough handling can damage the embryo in those seeds where the embryo does not fully occupy its cavity between the endosperm. Seed also can be damaged by temperature extremes, too much moisture, or lack of oxygen. To avoid seed damage the following procedures should be observed at all times:

1. Avoid rough handling of cones.
2. Store cones in sacks loosely. A good rule of thumb is to fill a sack one-half full with cones, (or one bushel of cones in a 2 bushel sack), and then tie the sack on the very top. This leaves the cones loose in the sack, air can move through it easily, and when the cones dry there is plenty of room for expansion and the cones will not case harden.
3. If interim storage in the field or at buying stations is needed, cones must be stored on racks in a shaded area. Sacks must be stored on these racks so that air can move around them freely.
4. When shipping cones to the extractory, use open trucks, do not stack sacks more than 2 high, use racks to space out the sacks, do not transport cones during extremely hot weather, otherwise use refrigerated trucks.
5. Often extended cone storage is required prior to extraction. Storage must be well ventilated, cool and dry. Various cone shed designs are available.
6. Protect cones at all times from rodent damage. This is particularly important for small lot tree improvement cones. It is amazing how fast a squirrel can go through a bushel of cones.

CONE AND SEED IDENTIFICATION

The best cone collection and seed treatment is of no value, unless proper cone and seed identification and records are maintained. The Bureau of Land Management is using a cone tag that can be used for reforestation cone collections (large lots) as well as tree improvement cone collections (small lots). The cone tag consists of two parts, the lower part is placed inside the sack of cones and the upper part is tied to the top of the bag on the outside. Each set of tags stays with the cone and seed lot at all times, even in the seed bank storage. We are using various colors to identify B.L.M. Districts.

All small lot collections are accompanied by a list of collections, usually in numerical order by parent trees. We have a standard form for this and it is also used as a work sheet for seed extraction and testing. All seed information is key-punched off of these sheets and put into computer storage, which is up-dated annually.

CONCLUSION

In order to accomplish quality cone collections it is important to do the following:

1. Know the "Reproductive Cycle" of the tree species to collect.

2. Know your seed bank needs.
3. Inventory and evaluate possible cone crops.
4. Develop a detailed cone collection plan.
5. Pick cones at the proper maturity.
6. Pick and handle cones properly.
7. Maintain cone and seed identity and records.

PUBLICATIONS CITED

To finish up, I would like to recommend a publication that I feel would help anybody very much that is starting to collect cones:

"Guideline to Collecting Cones of B.C. Conifers", by Dobbs, B.C.; Edwards, D.G.W. Konisha, G. and Wallington, D. Published by the British Columbia Forest Service and Canadian Foresrt Service, Joint Report No. 3, March, 1976.

USE OF SOLAR ENERGY TO DRY CONES AT THE ALBUQUERQUE TREE NURSERY

Atha Boyd Elliott[1/]

The construction and utilization of a solar energy seed extractory proved to be very efficient for drying cones in an expeditious manner with thermostatically controlled heat, plus gave us new and useful data for drying cones in the future.

Construction of the Albuquerque Tree Nursery seed extractory was completed for processing cones in the fall of 1979. The cones were processed from October 1979 to December 1979.

The extractory is 103.5 feet long running from east to west and 60 feet wide. The fiber glass cover over the roof holds the heat so it can be pulled down into the heating unit by fans on the north end of the building. There is no heat storage capacity. The north end of the extractory is equipped with thermostatically controlled dampers that will mix in outside air to maintain a maximum of 110^{o}F. Inside the extractory there are 5 main heat units; each unit breaks into three hookups for cone drying trays. Early in the seed year temperatures in excess of 130^{o}F were reached if only one heat unit was running. The 110^{o}F desired temperatures could only be maintained if other fan units were running. However, this was not the case later in the seed year.

The base tray hookups, base trays and drying trays were purchased from International Forest Seed Company in Birmingham, Alabama. Each 4' X 8' drying tray was designed to hold 6 bushels of green cones.

The trays with green cones are stacked 6 high when drying. In October, cones were ready to process in 5 days; later in the year the drying time increased to 7 or 8 days. If the extractory roof had a sharper peak for more solar contact later in the season, the drying time would probably decrease. Late in the season, the dampers never opened--even with only one unit running, and with heat being directed through one hookup.

It was necessary to store some cones in the sun while waiting for space to become available in the extractory. The parking lot to the west of the extractory is black top. When drying trays were placed on pallets, cones would be fully opened only 2-3

1/ Atha Boyd Elliott, Nursery Superintendent, Albuquerque Tree Nursery

days later than in the drying system. This was only in the early part of the seed year. The lower angle of the sun later in the year caused uneven drying of the cones due to shading of the cones by the south side of the drying tray. Physically moving cones caused damage to the drying trays. The problem was alleviated by placing outside sun-dried cones in the system a couple of days.

The Nursery extractory has exhaust fans directly above the drying units that come on when the heating unit is turned on. The fans are designed to prevent the incoming pressure from destroying the walls. This is not a practical problem as the overhead door is always open when the cones are being processed to move trays in and out. The high fans remove most of the heat making it uncomfortably cold to work at times. If the fans are installed, there are at least 2 acceptable alternatives to the Albuquerque design: Switches, so the fans could be turned on independently of the heating unit if the overhead door was closed, or place the fans on the opposite wall so the heat would circulate through the building before being drawn out.

Table 1 is a summary of temperature readings taken periodically throughout the seed year. Next year a greater effort will be made to obtain more data. The benefit of the solar drying system is obvious. Even on cloudy days, there was a substantial temperature increase in the drying trays over the ambient air temperature. The first 4 temperature readings are from probe thermometers, the last is an unsheltered hygrothermograph.

The Nursery will purchase 100 additional drying trays to dry cones on the black top at the west end of the extractory. This will make double shifting possible in the event of a big seed year.

TABLE 1

TEMPERATURE READINGS OF SEED EXTRACTORY HEATING SYSTEM

DATE	TIME	WEATHER	PROBE THERMOMETER MAIN CHUTE	PROBE THERMOMETER BASE TRAY	PROBE THERMOMETER #4 FROM BOTTOM	PROBE THERMOMETER ROOF	HYGRO-THERMO-GRAPH OUTSIDE
11/5/79	1400	Clear	84	79	78	58	68
11/6/79	0840	Thin clouds	58	58	56	47	40
	1225	Overcast	75	72	75	56	56
	1535	Thick clouds	60	60	60	57	57
11/7/79	0850	Thin clouds, no direct sun. Rain in a.m.	53	53	52	46	43
11/14/79	1000	Clear	65	62	58	44	47
	1200	Clear	78	75	71	50	44
	1400	Clear	72	72	72	56	64
	1600	Clear	58	57	60	58	60
11/15/79	0830	Clear	44	44	46	42	30
	1010	Clear	46	68	66	64	48
	1200	Clear	81	78	77	54	46
	1400	Clear	77	76	78	60	63
	1600	Clear	58	60	62	60	63
11/16/79	0830	Clear	44	44	46	42	30
	1230	Clear	82	80	80	60	50
	1400	Clear	78	78	78	60	74
	1600	Clear	64	67	64	64	63
12/5/79	0830	Few high clouds	46	44	No reading taken.	38	No reading taken.
	1000	Clear	85	79		51	
	1230	Clear	83	81		58	
	1400	Clear	78	80		58	
	1600	Clear	62	66		55	
12/6/79	1100	Clear	88	88	No reading taken.	46	No reading taken.
	1300	Clear	95	94		55	
12/7/79	0810	Clear	44	46	No reading taken.	39	No reading taken.
	1000	Clear	86	84		48	
	1230	Clear	98	100		54	
	1440	Clear	88	91		58	
	1600	Clear	62	64		59	

PRODUCTION SEED PROCESSING AT PINE RIDGE FOREST NURSERY[1]

D. Altmann, P. N. Au and L. Lafleur[2]

ABSTRACT

Pine Ridge Forest Nursery processes seed from cones collected by The Alberta Forest Service and forest industry in Alberta. The seed program involves cone storage and the extraction, cleaning, grading, storage and testing of predominantly white spruce and lodgepole pine seed.

INTRODUCTION

Pine Ridge Forest Nursery processes cones collected by the Alberta Forest Service and forest industry in Alberta. Extracted seed is used for production of bareroot or container seedlings at the nursery, seeding of harvested areas, or seedling production by forest industry.

The seed program at Pine Ridge Forest Nursery involves cone storage and extraction, cleaning, grading, storage and testing of seed. Seedlots are kept separate by provenance from cone collection to seed storage.

CONE STORAGE

Cones are collected off felled trees or from squirrel caches, and shipped to the nursery in two bushel (0.70 hectolitre) burlap bags. Each bag is tagged with two identity tags, specifying name of shipper, species, area and year of collection, e.g. DG 64-5-6-74 Sw. Each shipment of cones is accompanied by a prescribed document containing detailed information about the cone collecting area.

Cones are stored in three steel-frame sheds with large, wire-screened sliding doors and asphalt floors. Each shed can hold approximately 6000 bushels (2200 hectolitres) of white spruce cones or 18,000 bushels (6500 hectolitres) of lodgepole pine cones. Pine cones are stored in their burlap bags, about eight bags high. Spruce cones are stored loosed on burlap lined self-stacking pallets, about 1½ bushels per pallet; this allows for air circulation to dry the cones and discourages molding. A bumper crop of spruce cones in 1979 forced utilization of twenty container seedling greenhouses as additional space for air-drying: cones were spread out on the floor and periodically stirred.

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[1]Paper presented at the Intermountain Nurseryman's Association Meeting, Boise, Idaho, August 11-14, 1980.

[2]Respectively Research Forester, Production Forester, and Seed Program Supervisor at Pine Ridge Forest Nursery, Smoky Lake, Alberta.

SEED EXTRACTION

The seed extraction facility, based on a design of the Saskatchewan Forest Service, was built in 1978. It is capable of processing 50,000 bushels (18,000 hectolitres) of spruce and pine cones per year, on a one shift per day basis.

Seed extraction (and seed cleaning) are usually only carried out from November until March, on a twenty-four hours a day, five days a week schedule. This conserves energy and provides continuous employment. It also develops a versatile labour force because personnel is employed in seedling production during the remaining part of the year. The plant employs four people per eight hour shift to process cones and six people per shift to extract spruce cones. The weekly production is 3,300 bushels.

Spruce and pine cones are treated differently because scales of lodgepole pine cones are kept closed by a resinuous bond.

Lodgepole Pine

Bagged cones are moved on pallets from the cone storage sheds into the building by forklift. Cones are brought in from the cold a minimum of 16 hours before processing to ensure uniform cone temperature prior to scorching.

A hopper is filled with 30 bushels of cones by means of a conveyor, and the cones are slowly funneled through a revolving cone-shaped screen to remove needles and loose dirt. Subsequently they pass through a scorching unit, consisting of a 4-step vibrating pan and 6 gas-fired radiant heaters. This subjects the cones to a temperature of 210 - 230^{o}C during $1\frac{1}{4}$ - $1\frac{1}{2}$ minutes, and breaks the resin bond.

Cones are transported from the scorcher by means of a conveyor belt to four preheat bins. These bins utilize the exhaust heat from the kilns to precondition the cones before going into the kilns. This saves energy and time. The cones are fed into the preheat bins through a pivot-mounted auger. Water can be applied to the cones while they pass through the auger. Cones can remain for up to two hours in the preheat bins.

A batch cart on rails is filled from the bottom of a preheat bin and positioned over one of eight revolving drums in four individually controlled kilns to discharge the cones through a chute in the floor. The screened kiln drums are hexagonal in shape. Both the inside temperature of the kiln and the drum rotation speed can be varied to suit the species and seedlot being extracted. It is also possible to raise the humidity in the kiln by steam injection.

Pine cones remain in the 30 bushel capacity kiln drums for up to eight hours at a temperature of 60^{o}C. During this time they are rotated at 3 RPM for various periods of time. Seed falling through the rotating screens is periodically conveyed by vibration into wooden catch bins outside the kiln. This step provides continuous visual evidence of the progress of the extraction process, as well as the effects of varying the rate of rotation and tumbling schedule. Removing the seed from the kiln soon after release from the cone minimizes the time that the exposed seed is subjected to heat.

Winged seed is collected from the catch bins, bagged and put in cold storage until it can be cleaned.

Spent cones are removed after the extraction cycle is completed by reversing the direction of rotation of a drum, vibrating the cones through a chute in the floor and conducting them by means of a vacuum system into a large elevated hopper outside the building. Spent pine cones are sold to contractors for use in landscaping.

White Spruce

White spruce cones open partly during the drying process in storage. They are transferred from the pallets into open carts; one cart load contains 15 bushels of "green" cones or 30 bushels fully dried cones. Cones are conveyed directly from the cart by a vacuum system to a holding bin on the floor above the kilns; dust is collected in large canvas filter bags.

A batch cart on rails is filled from the holding bin and the cones are discharged in the kiln drums, where they remain at a temperature of 40°C for varying lengths of time and are tumbled for short periods at 8 RPM. Cones of high moisture content take somewhat longer to open before releasing the seed. The average extraction cycle takes four hours.

SEED CLEANING AND GRADING

The seed cleaning and grading equipment was designed by the Hilleshog Company in Sweden, and has operated for one season. The system consists of two scalpers, a wet dewinger, a liquid separator, a seed drier, a seed sizer and four gravity separators. The objective of this process is to obtain seed of high purity and viability and a seed moisture content of 5 to 8 percent.

Scalping

Winged seed is shaken out of bags into a vibrating hopper on rails and passes through one of two scalping units, i.e. a vibrating step-sieve for lodgepole pine seed or a vibrating screen for white spruce seed, to remove cone scales, needles, dust and other debris. The vibrating screen is used for seed of both tree species until modifications of the step-sieve are completed.

Dewinging

Winged seed is transferred to a wet dewinger. This is a 130 cm diameter rotating drum, open on one end, capable of holding about 400 litres of winged seed. The drum rotates at various speeds depending on the load size and species being dewinged. A full load of approximately 340 litres of winged seed is tumbled for 40 to 45 minutes. Water is added for 4½ minutes after the drum is filled. Air is blown continuously along the side of the drum to facilitate tumbling of the seed and to prevent sticking of the wi-ged seed against the sides of the drum. The moisture causes the wings to expand and the seed drops off. The wings and some empty seeds are blown from the drum by the continuous stream of air and fall into a chute below the drum for disposal.

Liquid Separator

Seed is removed by tipping the drum and discharging the seed onto a shaking screen which removes much of the small debris. The seed passes through a small hopper and is fed by a vibrator into a cup-shaped receptacle. Here it is mixed with running water and drops through a spout about 50 cm deep into a liquid separator which contains lukewarm water. The water removes resin, fungal spores, cracked seed and fine dirt. The seed floats up to the surface and seed and water flow into a feeding device for distribution over screened trays fastened to an endless variable-speed conveyor. The speed is regulated to cover the screens with seed to a depth of 2 cm.

Drier

These screens pass through three connected drying units (each unit has room for five trays) against the direction of forced air flow, i.e. the air is cool and moist at the entry of the first drying unit and warm (32°C) and dry (2-4! RH) at the exit of the last unit. The seed dries in one to one and a half hours. The drying process is monitored by periodic testing of seed moisture content at the end of the drying cycle by means of a grain moisture tester. A moisture content between 5 and 8 percent is considered satisfactory.

Seed Sizer

Dried seed falls into a hopper and is conveyed through a suction hose to a seed sizer, which consists of a series of shaking screens of various mesh sizes. Foreign matter and seed of four sizes are separated into five fractions.

Gravity Separators

The final step of seed cleaning is accomplished by means of specific gravity separators. Each seed size if funneled into its individual separator unti. Air flowing through a separator divides the seed by weight into three fractions, i.e. filled seed, empty seeds plus wing remnants, and poorly developed seed plus miscellaneous foreign matter. The air flow can be regulated to minimize loss of good seed. Each fraction is collected in plastic bins, but only the filled seed fraction is retained and packed in clear plastic bags, separately for grade A (largest two fractions), B and C (smallest fraction).

Packing

Seed is weighed in 10 kilogram lots, an identity tag is enclosed and the bag is double-sealed by heat. Sealed bags are packed in waxed cardboard boxes that can hold 10 or 20 kilograms of seed, waxed cardboard covers of similar size are slipped over the boxes, and relevant information is written on the side of each box cover (seedlot, species, seed grade and amount of seed). Samples for laboratory testing are taken for each seed grade before packing the seed. The seed is now ready for storage.

The whole operation is run by a crew of three per shift. The average production per eight hour shift is 140 kilograms of seed.

SEED STORAGE

The final production phase of the seed program is cold storage of seed at -18°C (0°F) and 50 percent relative humidity. A separate fire-proof concrete building has been designed to store 50,000 kilograms of seed within four freezer compartments, each with its own environment controls. It is built 1.80 metres below ground level in the side of a small hill. This results in conservation of energy and a more closely controlled environment. An important safety factor is that conditions will remain fairly stable for at least 72 hours in case of a power failure.

SEED TESTING

The seed testing laboratory is located on the second floor of the seed extraction building. It is equipped with four germination cabinets, a drying oven, an X-ray machine, precision balances and other apparatus.

Random samples of seed are taken from each of the three seed grades of every extracted seedlot and tested for purity, moisture content, germination rate and weight of 1000 seeds. X-rays are taken to detect damaged and empty seeds. Seed in cold storage is retested every second year for germination rate and moisture content.

Testing procedures are based upon the rules of the International Seed Testing Association (ISTA). A recent modification is that our germination rates are based only on the top four vigour classes according to a classification of Mr. Wang of the Petawawa National Forest Institute of the Canadian Forestry Service. This gives a better correlation with germination in the greenhouse.

Laboratory staff also stratifies seed for container seeding at the nursery.

A NEW PRECHILLING METHOD FOR TRUE FIR SEEDS[1/]

D.G.W. Edwards [2/]

ABSTRACT

Seeds of grand, subalpine and Pacific silver firs were prechilled, their moisture contents adjusted to four levels, then stored at 2°C. Non-dried seeds (45% moisture) could be stored only for 3 months before germination began. Seed quality deteriorated when seeds were stored at 45% for more than 6 months. Seeds air-dried to 35% moisture stored well for 6 months but germination began in storage after 9 months. Air-drying to 25% enabled prechilled seeds to be stored for 12 months without any significant reduction in germination. At both 35% and 25%, the effect of pre-chilling in increasing germination rate was retained. Although they did not deteriorate in storage, seeds oven-dried to 15% did not retain the prechilling effect.

INTRODUCTION

Most nurserymen have encountered, at one time or another, the problem of synchronizing the completion of seed prechilling (stratification) with the proposed sowing date. Prechilling consists of soaking the seeds in water for several hours, then refrigerating them; this treatment may last for a few weeks or several months, depending upon the species. Seed losses occur when germination begins in the refrigerator, a problem that is exacerbated when sowing is delayed. Circumstances sometimes prevent sowing all the prechilled seeds, raising yet another problem of whether to discard the surplus or dry them out and return them to storage.

Danielson (1976), reporting to the Western Forest Tree Seed Council, and Danielson and Tanaka (1978) concluded that ponderosa pine (*Pinus ponderosa* Laws.) seeds that had been air-dried to a moisture content of approximately 26% could be stored at 2°C for 9 months without losing seed viability or the prechill effect. Prechilled seeds of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) air-dried to 37% moisture could be held only for 3 months before germination began in storage. Non-dried, prechilled seeds of both species, with considerably higher moisture levels, began to germinate by the third month of cold storage. An obvious key in handling prechilled seeds is the control of moisture content and if this can be done successfully, two practical possibilities suggest themselves.

[1/] Paper presented at Joint Meeting of Intermountain Nurseryman's Association and Western Forest Nursery Council, Boise, Idaho, Aug. 1980.
[2/] Research Scientist, Canadian Forestry Service, Pacific Forest Research Centre, Victoria, British Columbia.

i) Prechilling could be applied relatively independently of sowing date. For example, ponderosa pine seeds could begin a 1-month prechill anytime up to 9 months before sowing.

ii) Date of sowing would become flexible, since there would be a period of several months in which seeds could be stored without germination beginning prematurely.

If seeds of other conifer species could be handled in the same manner, similar advantages might occur. Other reports (Vanesse 1967; Hedderwick 1968; Barnett 1972) have indicated that prechilled seeds may be dried and stored at low temperature without losing viability. However, the effect of the prechilling treatment in stimulating germination was lost, i.e., dormancy was reinduced, when moisture contents were reduced below 10%. The research reported here examined the effects of different drying treatments on the storage life of prechilled seeds of Pacific silver fir (*Abies amabilis* (Dougl.) Forbes), grand fir (*A. grandis* (Dougl.) Lindl.) and subalpine fir (*A. lasiocarpa* (Hook.) Nutt.)

MATERIALS AND METHODS

Two seedlots of grand fir (Ag 2903 and Ag 2899) and one each of Pacific silver (Aa 2717) and subalpine (Al 2900) firs were provided by the British Columbia Ministry of Forests. Before experimentation began, x-ray methods were used to remove empty and insect-damaged seeds. Seeds were prechilled by soaking in water for 48 hours, drained, then refrigerated at 2°C for 28 days in plastic bags.

Prechilled seeds were dried to three moisture levels, placed in dry plastic bags and returned to cold storage at 2°C for periods up to 12 months. Some seeds were air-dried for 1-4 hours at room temperature until their moisture content had decreased to 35%. Other seeds were air-dried for 6-12 hours to 25%, while the lowest moisture level, 15%, was reached after oven-drying at 30°C. Non-dried, prechilled seeds were also stored. Their moisture content, the highest tested, varied between 40%-50% among the seedlots, but was designated as 45% for convenience. Moisture contents were calculated after drying 4 samples of 50 seeds each for 24 hours at 105°C, and expressed as a percentage of seed fresh weight by the formula:

$$\text{moisture content (\%)} = \frac{\text{fresh weight} - \text{dry weight}}{\text{fresh weight}} \times 100$$

To arrive at the target moisture contents, 10 samples of 50 seeds each from each lot were dried for 24 hours at 105°C and the mean dry weight was calculated. This mean dry weight was used with each target moisture content (35%, 25%, 15%) to calculate the fresh weight to which similar sized samples of prechilled seeds had to be dried. In drying the prechilled seeds, the fresh weights of 6-8 samples were repeatedly monitored until the desired moisture content had been achieved. Subsequent checks showed that actual moisture contents reached by this method never varied by more than ± 2.5%.

Germination was tested on 4 replications of 50 seeds each in clear, covered plastic dishes containing one layer of Kimpak, which is a highly absorbent cellulose wadding, topped by three layers of white filter paper (Whatman No. 1) and 42 ml of distilled water. Temperature alternated daily between 30°C for 8 hours and 20°C for 16 hours, with cool-white fluorescent lights on during the higher temperature period. Germinants were counted daily during the peak germination period, then every second day, up to 28 days and they were evaluated according to the International Rules for Seed Testing (Anon. 1976). Germination percentages were transformed to arcsin and subjected to analysis of variance. Means were compared using the Student-Newman-Keuls' test (Steel and Torrie 1960).

Except for Pacific silver fir, for which the tests were limited by the number of filled seeds available to four storage periods, seeds were stored for 6 months without a significant reduction in average germination, irrespective of moisture level (Table 1). In subalpine fir, storage beyond 4 weeks promoted

Table 1. Average final germination (%) of four Abies seedlots after nine storage periods, irrespective of seed moisture level. Means within each seedlot followed by the same letter are not significantly different (P = 0.05).

Storage period	Seedlot number: Ag 2903	Ag 2899	Al 2900	Aa 2717
0 wk	62.6 ab	80.0 a	19.8 c	43.2 a
1 wk	73.1 a	73.1 a	23.5 bc	-
2 wk	70.6 a	75.6 a	23.1 bc	46.7 a
3 wk	68.5 ab	70.4 a	28.9 b	-
4 wk	71.7 a	69.6 a	30.8 b	38.7 a
3 mo	63.6 ab	72.1 a	40.2 a	42.5 a
6 mo	64.6 ab	66.7 a	42.9 a	-
9 mo	57.1 b	49.9 b	37.6 a	-
12 mo	47.3 c	47.3 b	38.6 a	-

Table 2. Average germination (%) of four Abies seedlots at four moisture contents, irrespective of storage period. Means within each seedlot and for each test period (14 or 28 days) followed by the same letter are not significantly different (P = 0.05). An asterisk indicates P = 0.01.

Seedlot	Days of test	Moisture Content: 45%	35%	25%	15%
Ag 2903	14	35.6 b*	72.1 a	41.4 b*	20.2 c*
	28	52.9 c*	80.5 a	68.2 b	55.8 c*
Ag 2899	14	40.7 b*	72.3 a	61.8 a	34.2 b*
	28	53.7 b*	76.7 a	76.2 b	62.2 b*
Al 2900	14	12.8 c*	43.8 a	33.3 b*	5.2 d
	28	19.9 c*	49.0 a	42.3 b*	15.7 c*
Aa 2717	14	6.3 b*	42.5 a	-	-
	28	25.1 b*	60.4 a	-	-

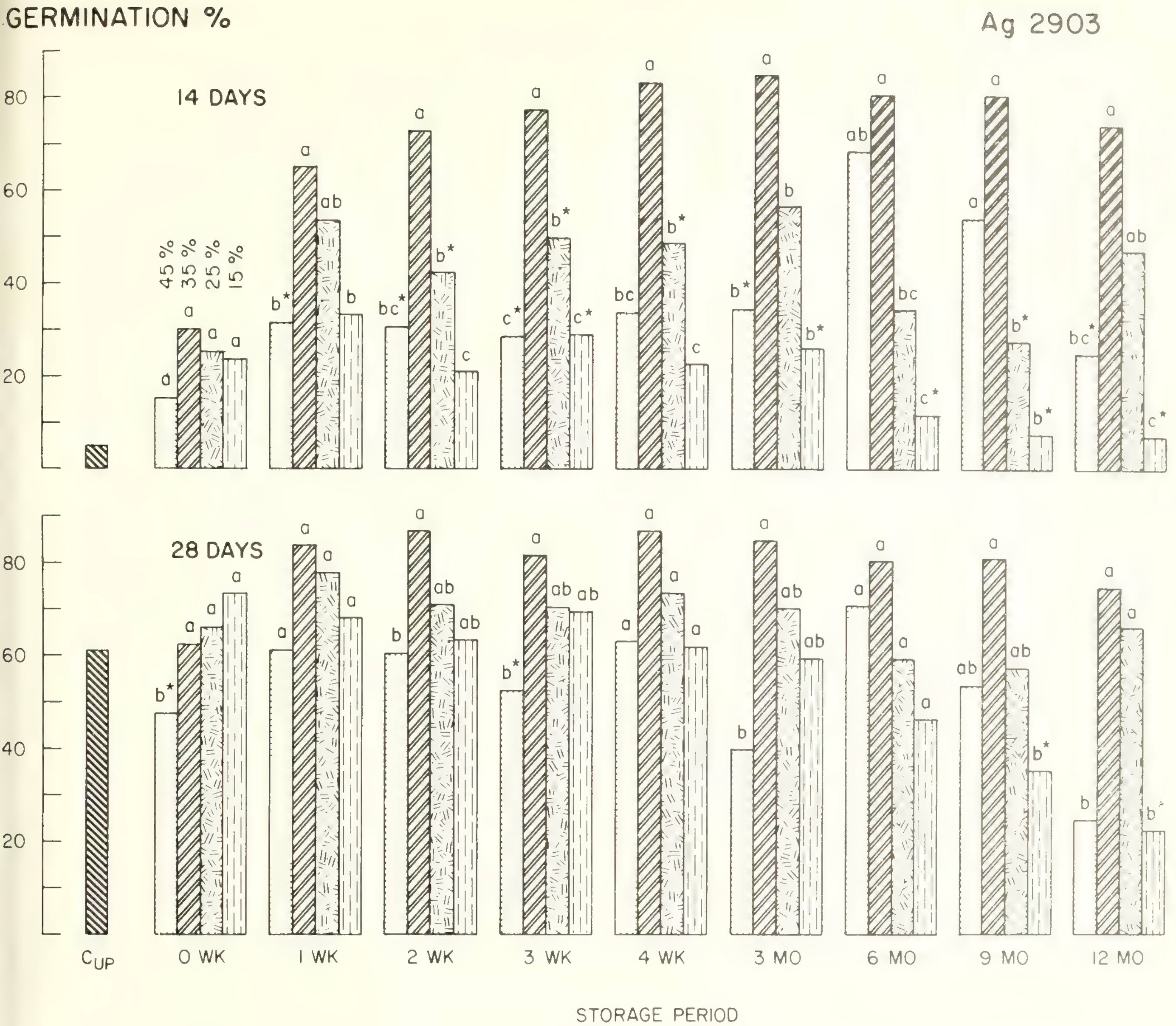

Figure 1. Effect of storage period and moisture content on germination rate (14 days) and final germination (28 days) of prechilled <u>Abies grandis</u> seeds (seedlot Ag 2903). C_{up}- unprechilled (unstratified) sample. Within each storage period, means followed by the same letter are not significantly different (P = 0.05). An asterisk indicates P = 0.01.

significantly higher average germination, irrespective of moisture level, a different response from that observed in grand and Pacific silver firs. This may be related to the fact that subalpine fir is a high elevation species in which a deeper dormancy may be encountered.

In all four seedlots, seeds that had been air-dried to either 35% or 25% moisture content prior to storage germinated significantly better than those oven-dried to 15% or those not dried at all (45%) (Table 2, Figs. 1-4). Irrespective of storage period, air-drying the seeds to 35% produced the best germination rate, as measured by germination percentage at 14 days of the test, and final germination (28 days) (Table 2). Compared to non-dried seeds (45% moisture), differences in all seedlots were highly significant (P = 0.01).

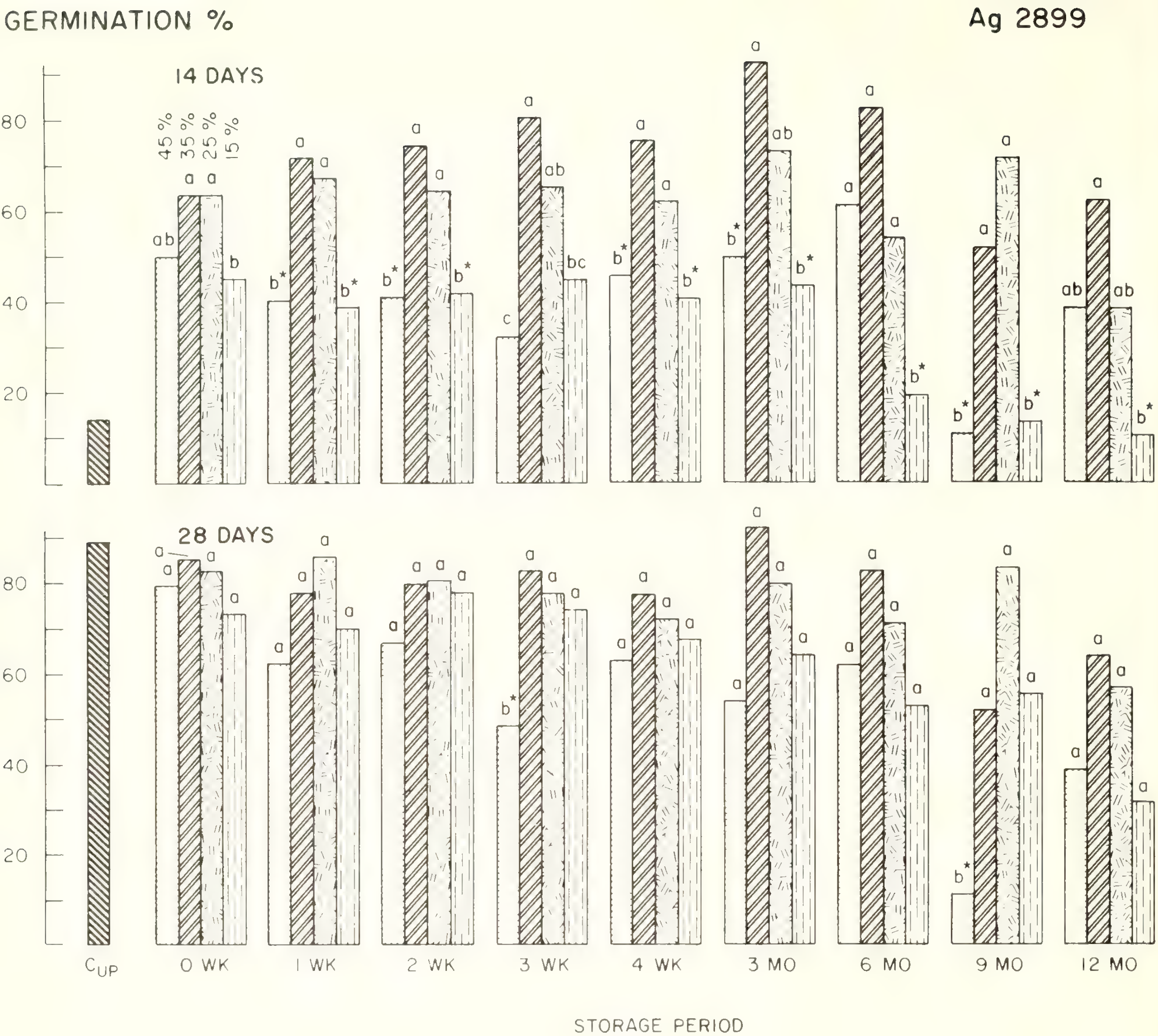

Figure 2. Effect of storage period and moisture content on germination rate (14 days) and final germination (28 days) of prechilled Abies grandis seeds (seedlot Ag 2899). C_{up}- unprechilled (unstratified) sample. Within each storage period, means followed by the same letter are not significantly different (P = 0.05). An asterisk indicates P = 0.01.

Storage of non-dried seeds amounted to a continuation of the initial prechill treatment, i.e., seeds stored for 4 weeks at 45% moisture in effect had been prechilled for 2 months, and considerable variability in germination was recorded in terms of variation among replications at any one storage period as well as between storage periods (Figs. 1-4). Variable germination after prechilling for several months has been observed in other studies (Edwards, unpublished data) and is probably related to high, uncontrolled seed moisture levels. In both the grand fir lots stored at 45% moisture, germination began before the 6 month storage was complete and accounted for almost all the seedlings produced at 9 and 12 months' storage. Germi-

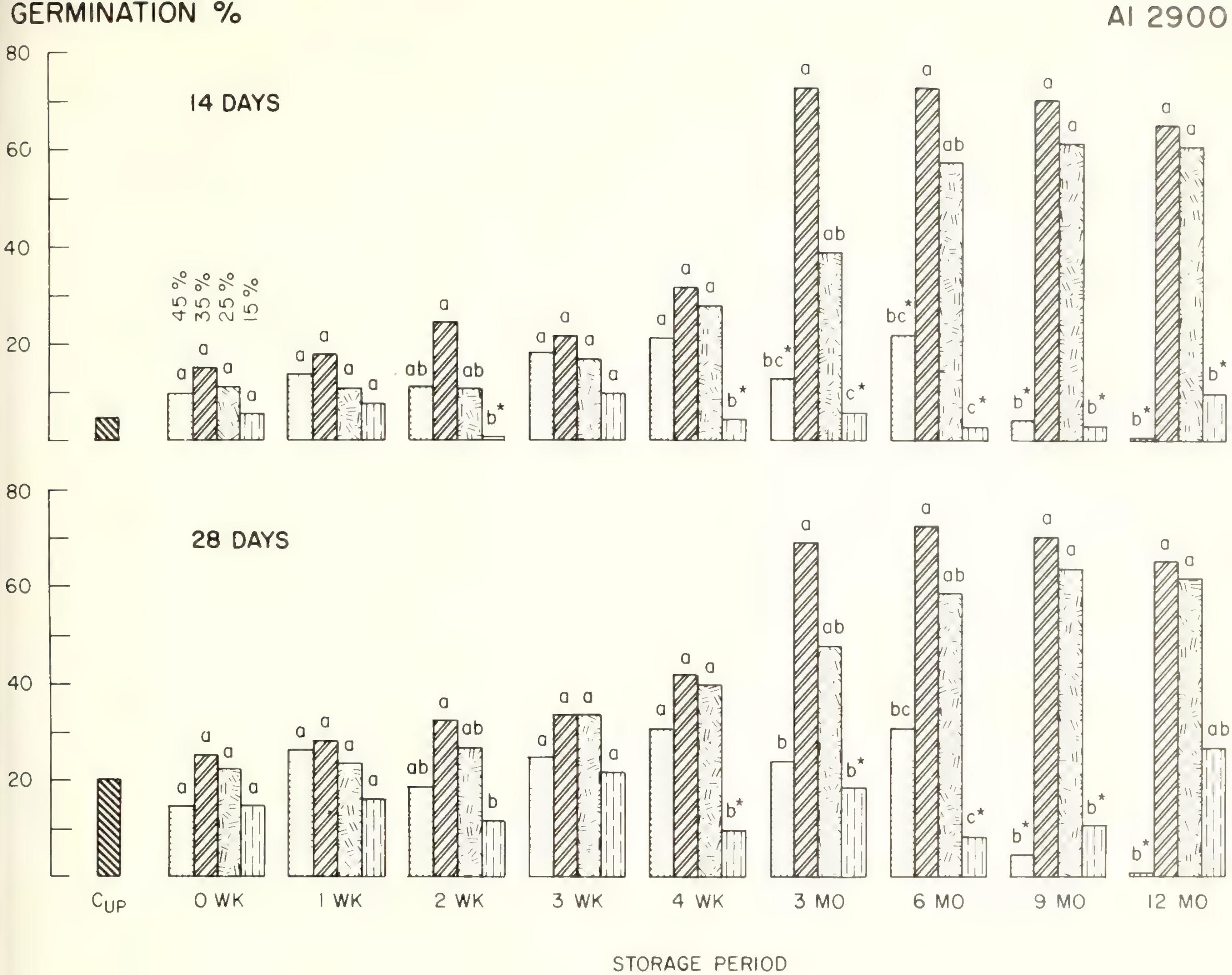

Figure 3. Effect of storage period and moisture content on germination rate (14 days) and final germination (28 days) of prechilled *Abies lasiocarpa* seeds (seedlot Al 2900). C_{up}- unprechilled (unstratified) sample. Within each storage period, means followed by the same letter are not significantly different (P = 0.05). An asterisk indicates P = 0.01.

nation during storage was included in total germination counts, so the reduction in final germination percentages in non-dried seeds stored for 9 and 12 months reflects a loss in seed viability. Air-drying to 35% prior to storage reduced germination during storage, but did not eliminate it. However, deterioration in seed viability at 9 and 12 months' storage was less than for non-dried seeds. Air-drying to 25% prevented emergence during storage and enabled the seeds to be stored successfully for 12 months, although germination was significantly lower than in seeds stored at 35% (Table 2). Oven-dried seeds (15% moisture) stored about as well as seeds not dried (45%), but not as well as air-dried seeds. The reduction in final germination at low moisture content was believed to be due to the reinduction of dormancy, rather than deterioration, since most of the ungerminated seeds remained viable.

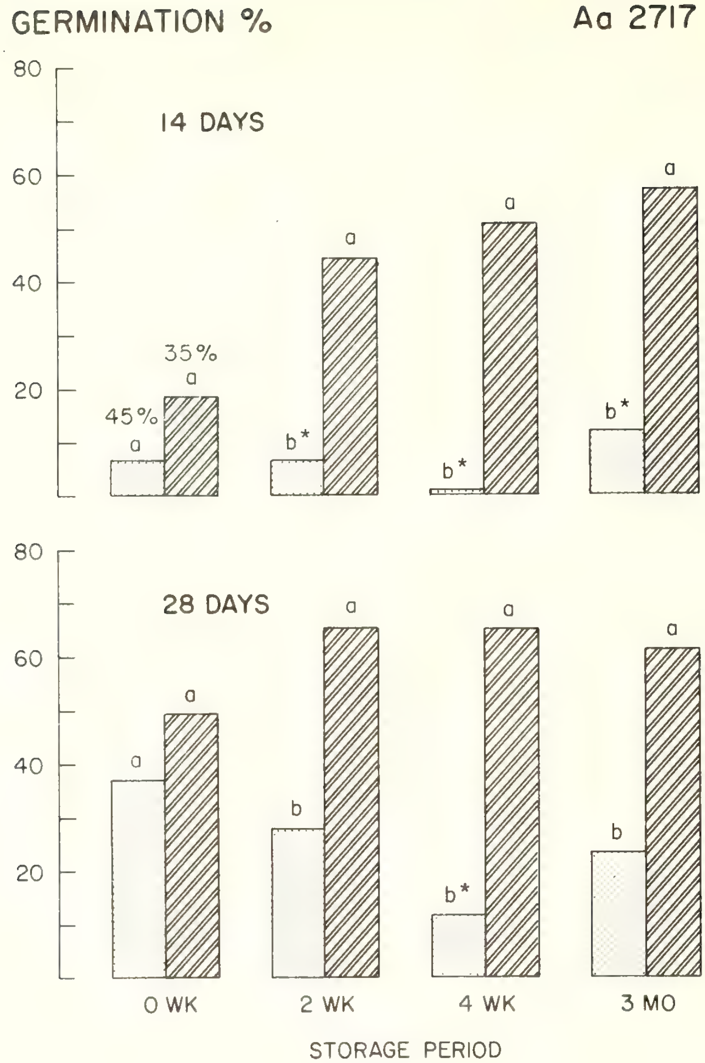

Figure 4. Effect of storage period and moisture content on germination rate (14 days) and final germination (28 days) of prechilled Abies amabilis seeds (seedlot Aa 2717). Within each storage period, means followed by the same letter are not significantly different (P = 0.05). An asterisk indicates P = 0.01.

As with most other presowing treatments, prechilling is performed to increase germination rate and it is effective in most Abies seedlots; total germination may also be increased sometimes (Franklin 1974). The 28-day prechill applied here (without drying) increased germination rate (percentage after 14 days of the test) in seeds stored for 0 weeks by a factor of between 2 and 3.5, but final germination percentages after 28 days were reduced, compared to unprechilled seeds (Figs. 1-3). When seeds were air-dried to 35% and 25%, germination rate and final germination percentage were increased, with maximum values of both parameters occurring at 35% with 3 months' storage in the two grand fir lots (Figs. 1-2) and with 6 months' storage in subalpine fir seeds (Fig. 3). Germination was so rapid when seeds were stored at 35% moisture for 3 months or longer that it was essentially complete (within 0.5% of the final germination percent) at 14 days of the test. These germination rates were between approximately 2 and 7 times greater than in seeds prechilled for 28 days (but neither dried nor stored) and were 6.5 to 17 times greater than in unprechilled seeds. In seeds not dried (45%), germination was essentially

complete at 14 days of the test only in seeds stored for 6 months or more, by which time losses in seed viability had begun. Storage for 9 and 12 months of non-dried seeds of seedlots Ag 2899 and Al 2900 reduced germination rates below those in unprechilled seeds. Tests on another 30 seedlots have confirmed that air-drying prechilled *Abies* seeds to 35% followed by 3 months' storage produces better germination than prechilling alone (Edwards and Leadem[1/], unpublished).

These results demonstrate that not only can prechilled *Abies* seeds be safely stored for periods up to 12 months without significant losses in total germination, but that air-drying stimulates germination to much higher levels than achieved by prechilling alone. Moisture content is a critical factor governing the period of safe storage. Maximum germination occurs in seeds air-dried to 35% but, since germination begins in storage, this moisture level is unsuitable for holding seeds more than 6 months. Moisture contents must be reduced to 25% to eliminate germination in storage. These observations are supported by those of McLemore and Barnett (1968) that dormancy in loblolly pine (*Pinus taeda* L.) seeds was greatest when they were stored at moisture contents between 10-18%. Dormancy was less at both higher and lower moisture contents, being least when seeds were stored above 20%. However, loblolly pine seeds with 20% or more moisture deteriorated more rapidly than those stored with 10% or less.

The increases in germination achieved by air-drying and storage should be advantageous in the nursery, even if there is no requirement *per se* to store pre-chilled seeds. It is not known if the procedure can be adapted for use on other tree species but this will be the subject of future work.

ACKNOWLEDGMENT

The technical assistance of D.W. Taylor is acknowledged.

[1/] British Columbia Ministry of Forests.

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SEED PROCESSING: MANAGEMENT TECHNIQUES[1]

Frederick Zensen[2]

ABSTRACT

Management techniques to help meet the basic objective of seed extraction: High quality clean seed, are presented. Seed extraction based upon the five component management framework: Planning, Organization, Motivation, Control, and Innovation is explained.

INTRODUCTION

In recent years there has been an increased emphasis on tree seed quality for Nurseries. This is due in part to the reduction of broadcast sowing, the advent of more precise seed drills, and for the large part increased container grown stock. All this has led to the continued development of new and better seed cleaning equipment; i.e., Missoula dewinger, Barnes separator, International Forest Seed Company kilns, Oliver Destoner, and the increased use of seed monitoring equipment; i.e., H. P. Faxitron X-Ray.

My purpose is not to address the equipment improvements, but rather management techniques for seed processing (extraction and cleaning). The question might be asked, "What management techniques for seed processing? All that need be done is clean the seed." This may be sufficient for some seed processing plants and you may get adequate results, but for the reasons cited above seed processing management needs further analysis and emphasis in Nursery operations.

BASIC SEED PROCESSING PLANT

Most typical extraction facilities will follow a similar line; that is, cone reception and storage, extraction, cleaning equipment, and seed testing. This last item may or may not be accomplished at the Nursery. Naturally, the type of equipment for each step in the process will vary at each Nursery. However, the objective of each facility remains the same; to extract and clean seed. How this objective is accomplished is what I wish to discuss.

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[1]Paper presented at Western Forest Nursery Council Meeting, Boise, Idaho, August 12 - 14, 1980.

[2]Forester, USDA - Forest Service, Coeur d'Alene, Idaho.

MANAGEMENT OBJECTIVE

The basic management objective in a seed extractory is the attainment of quality seed. Quality is defined as good vigor, high purity percent, and germination percent. The management process to achieve this objective, or any objective, may be separated into five parts: PLANNING, ORGANIZATION, MOTIVATION, CONTROL, AND INNOVATION (Batten 1969). Each part is dependent upon the other. Seed extraction easily fits into these five areas.

Planning

By July of the extraction year a fair estimate of cone crop size should be available to the manager. With this information it is then possible to plan budgeting data: cost, length of time to accomplish the job, size of crew, equipment needs, and contingencies. These items are the very least required of a good extraction plan.

Organization

Organizing the job is where crew deployment takes place. A manager should know the people in the crew and how to best deploy them; i.e., what they are best suited to do. Not all crew members function at the same levels. This is where skillful managers can best organize the utilization of their crew.

Motivation

Motivation is a very fragile word. The concept is not that difficult to understand. Webster defines motivate as (1) some inner drive, impulse, intention, et cetera, that causes a person to do something or act in a certain way; incentive, goal. Dwight Eisenhower is quoted as saying "Leadership is the ability to get a person to do what you want him to do when you want it done, in a way you want it done, because he wants to do it." I feel this is the core of seed extraction management.

Control

Control can be obtained in a few ways. As a manager you can be in the extractory checking on the crew's work constantly, or you can establish checks at various points in the process. If an accountability system is established, the spot check works rather well.

Innovation

In seed extracting this is, and must be, an on-going process. There is no single best method of cleaning seed. Each seedlot is slightly different. The size, weight, and shape of seed differs not only between lots but also within lots. The crew often times can be the best source of new ideas.

MANAGEMENT METHODS AT COEUR D'ALENE

The primary ingredient in any operation is a good crew. This is simple to state and also the answer to many management functions. Obtaining a good crew is not so easy and yet with a little effort not that difficult to achieve.

If you accept the management principle that people must have an interest in what they are doing and understand where they fit in (Boyd 1976), as well as a quantitative goal to try and accomplish, then you will agree in principle with this paper. Also, it must be understood that whether or not a group accepts management's objectives depends not only on what is demanded but also on how it is demanded. (Strauss and Sayler 1972).

My procedure at the Coeur d'Alene Nursery is as follows: The Nursery has established minimum purity standards for each species which we clean (Table 1). These standards are made known to each crew member before the start of extraction (the standards are re-evaluated each year to reflect the state of the art). In doing this I accomplish two points: (1) Management objectives are explained to the crew, and (2) A quantitative goal is presented. It is also explained that when each new seedlot is tested for purity and falls below the standard, it will be tagged with yellow flagging and must be recleaned. This, coupled with the fact that as a seedlot is processed from tumblers to scalper to dewinger to fanning mill to pneumatic separator, the operators of each piece of equipment sign off on the lot, instills quite a bit of pride in work as well as a sense of accomplishment. When the system was first instituted on those few lots that needed further processing, crew members took it as a personal affront to receive a yellow flag. That's a nice type of management problem to deal with.

Table 1.--Minimum purity standards, Coeur d'Alene Nursery

Species	Pure seed by weight
Grand fir	95%
Subalpine fir	95%
Western larch	90%
Engelmann spruce	95%
Lodgepole pine	95%
Western white pine	92%
Ponderosa pine	97%
Douglas-fir	95%

How does our crew accomplish the task of cleaning seed to a predetermined purity? The obvious answer is training and communication. This does not mean providing information. Often managers tend to equate information with understanding. This can lead to problems. Managers must communicate for the purpose of obtaining a level of understanding by crew members (Miller and Steinberg 1975). In 1978 the Coeur d'Alene Nursery processed 14M bushels of cones yielding 10M pounds of seed. This was accomplished with a neophyte crew. They had never cleaned seed before.

Each piece of equipment was explained as to its function and how it worked. Crew members were given instructions as to their equipment operations and after a short break in period told to clean seed. On those machines with different screens, starting points were established for each species and crew members were told to experiment for themselves to decide which other screens would work best, again keeping in mind the production goals. This free reign further installed a sense of accomplishment and pride in work. As notes were compared crew members began to agree with my statement that each seedlot is different regardless of species, and certain standards began to be established as starting points for cleaning. Often times they were not in agreement with my original suggestions. Innovation or new methods to clean seed are often brought out by crew members. I feel it is important that they are given the freedom to try these techniques once they have been discussed with management. A successful process which we use for pitch removal on western larch came about after such a discussion.

It was also necessary to explain to crew members what to look for in seed cleaning, which trash could be removed in certain ways, and to explain that while seed cleaning is not hard work, it does require patience. One must accept each seedlot as a challenge to clean it to a certain standard. At Coeur d'Alene the crew members also participate in both bareroot and container sowing operations and therefore have the opportunity to see the fruits of their labors or past errors as well as an understanding of where they fit in the scheme of things. Monitoring is accomplished with an X-Ray unit at various points in the process. It is done not to criticize the operators of equipment but as an instructional tool to help them accomplish management's goal of high quality seed.

CONCLUSION

By spending some time explaining to your extraction crew the importance of seed processing in the entire scope of Nursery operation, I believe you will be able to increase seed quality. I define this as increased purity, in most cases germination, and perhaps a slight reduction in yield. This reduction is due in part to more attention to trash removal and an unwillingness to let a dirty lot slide by.

Communication between people allows you to mold a good crew. It is a rare occurrence when a group of people are placed together and work well together instantly. A good manager must observe and follow the five step management process: Planning, organization, motivation, control, and innovation to achieve the desired objective.

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QUICK TEST VS. STANDARD GERMINATION TEST[1]

Ed Hardin[2]

ABSTRACT

Three "quick tests" were compared with standard germination tests on lots of Douglas fir, Pinus species, Abies species, spruce and bitterbrush. All three tests, when properly performed and evaluated, can predict viability which correlates with the standard germination tests on the same sample, except in Abies species. All "quick tests" indicate higher viability on Abies than was obtained by the standard germination test.

Germination by standard procedures under ideal conditions have long been used by nurserymen to establish viability of tree seed lots. Standard germination tests are a long, drawn-out process for most tree seed, requiring long periods of stratification under cool, damp conditions, followed many times by equally long periods in germinators under optimum conditions for the particular kind of seed. Many things can happen to seed under such conditions. Questions have been raised concerning the ability of these tests to determine the full potential of the seed. Also, because of the time required to complete the standard germination tests, the nurseryman often cannot use them in his decision process.

For these reasons, the Oregon State University Seed Laboratory has for years worked on "quick tests" which could provide information to the user more rapidly than standard germination tests. Years of effort and research have gone into refining techniques which would better correlate these quick tests with maximum germination. We feel that these correlations have been very good in recent years and would like to share a summary of some results. I hope they will acquaint you with the tests and build confidence in their results, so that they can be used to your advantage when making decisions concerning the seed you will plant to produce future tree crops.

The three tests compared here with standard germination are the tetrazolium test (TZ), which takes two days for completion, the hydrogen peroxide test, which requires eight days, and the X-ray test which can be completed during a working day. Standard germination of most tree seeds requires four to twelve weeks.

Details for conducting the tests were discussed by Rodger Danielson and are printed in your 1972 proceedings, therefore, I will not go into procedural details. If interested, you can look up the 1972 proceedings and follow his well-described instructions.

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[1]Presented to the joint meeting of the Western Forest Nursery Council and the Intermountain Forest Nurseryman's Association, Boise, Idaho, August 12-14, 1980.

[2]Coordinator, Seed Services, Crop Science Department, Oregon State University Corvallis, Oregon 97331.

1978-79 was a good tree seed year in many parts of the West, as most of you are aware. Seed supplies were low and seed was badly needed by many nurseries. There was extreme pressure on the part of some to plant seed the same year it was collected. Some reported to me that seed had been planted without the knowledge of its viability. Various quick tests were used by some to help in decision making. The results of these tests are the data used in this paper.

I would first like to discuss the TZ test as it compares with standard germination. Tetrazolium chloride is a colorless solution. When it comes in contact with hydrogen, it forms a red pigment called formazan. Live seeds release hydrogen during the germination process. This happens very soon after water is introduced and the very first stages of germination are initiated. It was determined that if tetrazolium was introduced into seeds, those live parts would turn red and those dead would not stain. By careful observation and a knowledge of the morphology and physiology of the seed, a trained technician can determine abnormal staining from normal staining, thereby correlating the TZ test with the normal, abnormal and dead seed found in a standard germination test.

Table I compares four species of tree seed and one shrub seed on a number of different tests. Forty-seven lots of Douglas fir were tested by both TZ and standard chill and no-chill germination. Results of forty-seven tests were averaged so that a comparison could be made. The results of the TZ test were very close to both the chill and no-chill. The same was true for 45 lots of pine. In comparing 27 lots of Abies, the TZ test averaged somewhat higher than both chill and no-chill. This concerns us. Abies are a difficult species to work with, as most people working with them realize. It is often difficult to obtain high germinating lots. There seems to be considerable variation within lots. We are concerned that perhpas the proper germination conditions have not been developed to obtain the maximum germination. There may be inherent reasons, however, that deteriorate a good embryo during its germination period and in this case, the TZ may not represent what a seed would do in a planting bed. More research is needed in the case of Abies. Spruce compares favorably in the two lots compared. Many of the shrub species are dormant and difficult to germinate. Standard germination tests are not developed for some species. We have developed TZ techniques on most shrub seed being used. The TZ test on three bitterbrush lots correlated favorably with the chill germination results. These lots obviously need chilling to break dormancy since the no-chill germination test produced no seedlings.

The second test discussed is the hydrogen peroxide (H_2O_2) test. It was determined that if this material was introduced into the seed, the embryo would elongate rapidly. By evaluating the embryo development, a judgment could be made and the results could then be compared with a standard germination test.

Table 2 first compares 50 samples of Douglas fir seed tested by H_2O_2 and then followed by standard no-chill and chill germination tests. The peroxide test correlates very well with the chill but obviously some lots of Douglas fir seeds need chilling since the average no-chill was considerably below the chill method. This same trend held true for the two Pinus lots and 21 lots of Abies. It would appear that this test rather accurately predicts the potential germination of the seed.

In Table 3 we were able to compare the X-ray test with TZ and standard chill and no-chill germination test. In comparing the results of 25 lots of Douglas fir seed, it would appear that the TZ came closer to the average chill test than did the normal reading of the X-ray test. This may indicate that the X-ray is not quite as definitive as a TZ test, but is still a good indicator of the potential germination of a seed lot. In comparing the results of three Abies lots, it would appear the full

potential of the seed was not realized in the germination test. TZ and X-ray compared favorably but were much higher than the standard germination.

In summary, the results would indicate that the three "quick tests" discussed here are good indicators of potential seed viability. The Abies results did not compare as well as the other species. One can only speculate why quick tests indicate higher viability in Abies than is obtained by standard germination. With good "quick tests" available, a nurseryman should not have to sow without knowledge of the viability of his seed. More than one viability determination on high value seed may be in order so that the nurseryman can better choose lots for seeding and thereby maximize his production.

TABLE 1. Comparison of seed viability of various species as determined by TZ and standard laboratory germination tests. Results shown are averages of all samples tested.

Species	Number Samples Tested	TZ	% Germination No-Chill	% Germination Chill
Douglas Fir	47	87	86	89
Pinus Spp.	45	81	79	79
Abies Spp.	27	67	45	49
Spruce	2	97	98	97
Bitterbrush	3	53	0	52

TABLE 2. Comparison of seed viability of various species as determined by H_2O_2 and standard laboratory germination tests. Results shown are averages of all samples tested.

Species	Number Samples Tested	H_2O_2	% Germination No-Chill	% Germination Chill
Douglas Fir	50	80	74	82
Pinus Spp.	2	87	69	84
Abies	21	62	48	57

TABLE 3. Comparison of X-ray, TZ and standard germination tests conducted on various species. Results are averages of all samples tested.

Species	Number Samples Tested	TZ	X-Ray Normal	X-Ray Questionable	X-Ray Total	% Germination No-Chill	% Germination Chill
Douglas Fir	25	87	90	7	97	79	84
Abies Spp.	3	69	63	21	84	47	44

SCHEDULING IRRIGATION TO INDUCE SEEDLING DORMANCY[1]

Joe B. Zaerr, Brian D. Cleary, and James L. Jenkinson[2]

ABSTRACT

The dormancy of seedlings can be induced by increasing plant moisture stress in early summer to midsummer. Each nursery should tailor its irrigation schedule to achieve early seedling growth, then dormancy induction, and finally dormancy deepening to produce planting stock with high survival potential.

A seedlings's ability to survive in the field is closely linked to its state of dormancy (Tinus 1974; Lavender and Cleary 1974; Cleary, Greaves, and Owston 1978). When fully dormant, seedlings can easily tolerate frost, brief exposure of roots to the atmosphere during lifting, root pruning, and cold storage. Because nursery practices invariably influence seedling dormancy, knowledgeable foresters now wisely demand that nurseries insure dormancy in every seedling crop.

In Oregon's Willamette Valley, seedling top growth must be stopped by late summer or early fall to avoid fall and winter frost damage. To prevent such damage and promote both morphological and physiological quality, seedling dormancy must be induced by late summer. Although the onset of dormancy may be hastened by decreased photoperiods and reduced nutrient levels, the desired effect is most easily and consistently achieved by increasing plant water stress. The nursery irrigation schedule is, therefore, the key to inducing dormancy.

Of course, no single "magic formula" exists. Irrigation schedules must accommodate specific nursery climates and particular cultural regimes to produce plantable seedlings. This paper describes the development of optimum irrigation schedules for the Dwight L. Phipps State Forest Nursery at Elkton, Oregon.

PROCEDURES AND RESULTS

To determine optimum water regimes for 2-0 Douglas-fir, various irrigation regimes were tested annually for three years.

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[1]Paper presented to the Intermountain Nurseryman's Association and Western Forest Nursery Council, Boise, ID, Aug. 12-14, 1980.

[2]J. B. Zaerr is an Associate Professor and B. D. Cleary is a Reforestation Extension Specialist, School of Forestry, Oregon State University, Corvallis, OR; and J. L. Jenkinson is a Forest Geneticist, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA. The mention of trade names or commercial products in this publication does not constitute endorsement or recommendation for use.

1974 Trial

Plant moisture stress (PMS) was measured with a pressure chamber[3] for three different water regimes (wet, 5 bar PMS; medium, 8 bar; dry, 15 bar) established for comparison with standard nursery practice. Treatments were begun in spring of the second growing season. The seedlings' internal moisture stress was monitored to determine the time to water and water applied when predawn PMS in seedlings exceeded the assigned treatment value.

The medium (8-bar) and dry (15-bar) regimes induced seedling dormancy in summer. Under the wet (5-bar) and standard nursery regimes, seedling tops still were growing in the fall and remained succulent in November. The dry regime reduced growth such that the resulting seedlings were too small. Predawn PMS in the dry regime did not reach 15 bar until mid-August, although average predawn PMS was much less because a week or more was required after each irrigation to again reach 15 bar. Predawn PMS of standard nursery practice closely approximated that of the wet regime and did not exceed 5 bar until late summer.

1975 Trial

Two regimes were tested in the second trial but differed from the first in that predawn PMS was increased during the growing season. Standard nursery practice was unchanged.

Treatment regime	Predawn PMS (bar) May 1	Jul 1	Jul 15	Aug 15
Wet	5	5	5	10
Dry	10	15	15	15

Seedlings in the wet regime were not sufficiently dormant in fall. Seedlings in the dry regime went dormant in summer but were again too small to meet the minimum size standards for plantable seedlings. If dormancy is to be regulated, size of seedlings must be controlled by the conditions during spring and early summer.

1976 Trial

The results of the 1975 trial indicated that, for 2-0 Douglas-fir, an intermediate water regime would strike a good balance between seedling size and dormancy in fall. That intermediate regime and its modifications for 1-0 and 2-1 Douglas-fir were tested in 1976.

[3]PMS Instrument Co., Corvallis, OR 97330.

Seedling class	Predawn PMS (bar)		
	Until Jul 1	Jul 1-Aug 1	After Aug 1
1-0	5	5	10
2-0	5	7	12
2-1*	5	10	15

*On hot days, seedlings were watered as needed for cooling.

These regimes allowed adequate seedling growth in spring and early summer and induced early dormancy to virtually eliminate shoot growth in fall.

DISCUSSION

The irrigation nursery schedules developed at Elkton were adopted as standard practice to insure seedling dormancy in fall and eliminate the potential for frost damage. Subsequent nursery and field experience generated a few refinements, which were incorporated into the 1979 irrigation schedules (Table 1).

Table 1.--*Generalized irrigation schedules for various seedling classes of Douglas-fir in the Phipps Nursery, 1979*

Seedling class	Predawn PMS *(bar)*			
	Until Jul 9	After Jul 9	Aug 3	Aug 20
1-0	5	10	12	15
	Until Jun 1	Jun 1-15		After Jun 15
2-0	5	8-10		15[1]
	Until Jul 1	Jul 1-Aug 1		After Aug 1
2-1	7	10		15

[1]In seedlings held for 2-1, keep predawn PMS between 10 and 15 bar.

Our experience reinforced the following:

1.--Any schedule still is only a guide. In 2-0 seedlings, for example (Table 1), the 8- to 10-bar stress was applied later in the season if seedling growth was not sufficient, that is, beginning June 8 for certain nursery blocks, June 15 for some blocks, and June 22 for still others. Schedules based on predawn PMS also must take into account maximum stress levels reached during the day. Windy conditions and/or low humidities can substantially increase PMS for a given predawn level. Soil texture also can affect maximum water-stress levels. Consequently, each

nursery must develop its own guidelines to meet the local soil and weather conditions while considering different cultural practices and seedling size objectives.

2.--What works well at one nursery may not work at another. At the U.S. Forest Service Humboldt Nursery near McKinleyville, California, early frost is not a problem. The nursery goal--a harvest of plantable, dormant seedlings--remains the same as at Phipps, but its attainment requires a different combination of cultural practices. Undercutting seedlings in midsummer of their second year is standard practice. In a 1978 study, the best 2-0 seedlings were produced by combining a single, early-July undercut with a 5-bar predawn stress regime.[4] Further, two nursery sowings are now common, one in March-April and the other in May-June (the traditional period). For these reasons, the 1980 irrigation schedules for Humboldt (Table 2) differ from those of Phipps in several respects.

Table 2.--*Generalized irrigation schedules for various seedling classes of Douglas-fir in the Humboldt Nursery, 1980*

Seedling class	Predawn PMS *(bar)*		
	Until Jul 15	Jul 15-Sep 1	After Sep 1
1-0 Early sow	5	5	5
Late sow	5	5	5
	Until Jun 15	Jun 15-Sep 1	After Sep 1
2-0 Early sow[1]	5	6-8 (10)	5
Late sow[2]	5	5	5
	Until May 1	May 1-Sep 1	After Sep 1
3-0[3]	5	6-8 (10)	5

[1]Undercut at 15 cm in March/April and again at 20 cm in July if held for 3-0.

[2]Undercut at 20 cm in July.

[3]Undercut at 20 cm in March/April.

Humboldt's generally lower predawn PMS is effective for two reasons. First, the fall is usually mild--often warm until November; frost damage has not occurred in the nursery's history. Second, for 2-0 seedlings, the midsummer undercut effectively stimulates root growth and stops shoot growth. Midsummer removal of a major portion of the seedling's water-absorbing surface apparently substitutes for high predawn PMS in late summer. Under these cultural regimes, both 1-0 and 2-0 seedlings have consistently survived and grown well in the field (Jenkinson and Nelson 1978; Knight, Nelson, and Jenkinson 1980). At Humboldt, undercutting in early fall and/or predawn PMS over 6 to 8 bar in fall are associated with reduced field survival.

[4]Administrative study directed by William I. Stein, Pacific Northwest Forest and Range Exp. Stn., Corvallis, OR, and monitored by James A. Nelson, Humboldt Nursery.

3.--Plant moisture stress should be reduced in the fall. In another experiment, higher moisture stress applied between mid-July and late August consistently halted shoot growth and increased cold hardiness of Douglas-fir (Blake, Zaerr, and Hee 1979). Delaying onset of the stress period until late August negated the effect on hardiness. A stress level of 10 to 15 bar also induced bud set and prevented late flushing but did not increase hardiness over that of the 0- to 5-bar controls. Seedling moisture stress apparently must be alleviated in fall if the hardening process is to be enhanced.

The dormancy process must be deepened once induced. For this reason, irrigation during early fall may be necessary to insure adequate moisture to complete this phase of the dormancy cycle before temperatures become too cold (Lavender and Cleary 1974). Irrigation should, therefore, be started when firm winter buds are evident and fall rains would normally begin.

CONCLUSIONS

Irrigation control is essential for producing bare-root seedlings of Douglas-fir with high survival potentials. By programming plant moisture stress, the nursery may regulate seedling growth, induce seedling dormancy, and enhance cold hardiness. The principles are simple:

- Monitor predawn PMS in seedlings to schedule irrigation.
- Promote growth early in the season.
- Induce dormancy in late summer by increasing PMS in early summer to midsummer.
- Complete dormancy deepening and enhance cold hardiness (frost tolerance) by reducing PMS in early fall.
- Tailor the irrigation schedule to accommodate the particular nursery soil, climate, seedling class, and cultural practices.

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THE CRANBERRY GIRDLER IN CONIFER NURSERIES OF WESTERN WASHINGTON AND OREGON[1]

Mark E. Triebwasser and David L. Overhulser[2]

ABSTRACT

The cranberry girdler (Chrysoteuchia topiaria, Zeller) has been identified as an insect problem in some conifer nurseries. The life history of this insect and means for control are discussed.

The cranberry girdler (Chrysoteuchia topiaria, Zeller), a sod webworm, is becoming a problem in several conifer nurseries in Washington and Oregon. A sod webworm larvae was first suspected of causing damage to tree seedlings at Weyerhaeuser's Jefferson Nursery near Salem, Oregon, in 1974. In 1975 a severe outbreak occurred at the Weyerhaeuser Mima Nursery near Olympia, Washington, and has been endemic at that nursery since. The insect was positively identified in 1979 as the cranberry girdler. The larval damage has also been identified at several additional nurseries in Washington and Oregon (Table 1), although there has been some confusion concerning the casual agent. The damage now assumed to be from the cranberry girdler has been attributed to strawberry root weevil, cutworm and mice.

The damage generally occurs in scattered patches where almost all seedlings are injured. In severe infestations, losses can exceed 25 percent of the seedlings in a bed. Generally little evidence of damage from the girdler is found until the time of lifting. Then the damage is readily apparent as bark feeding on the main root at or just below ground line.

The reason for lack of early evidence of larval feeding is apparent after examining the life cycle of the cranberry girdler. The adults emerge during late June and early July. The moths can be seen flying in the trees in quick, jerky movements, especially during the morning hours. After emergence, the moths mate and the female begins laying eggs on the second day (Kamm, 1973). Egg laying continues for about one week. The eggs hatch in 12 days and begin feeding (McDonough & Kamm, 1979). The larvae are small and it is not until late August and September that they are very actively feeding. It is then that most damage occurs. During October, feeding stops and the larvae form hybernacula in which they spend the winter before forming pupae in the spring (Kamm, 1973).

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[1]Intermountain Nurseryman's Association, Western Forest Nursery Council, Joint Meeting, Boise, Idaho, August 12/13/14, 1980.

[2]Nursery Technologist, Weyerhaeuser Washington Forest Nursery, Olympia, WA 98502, and Entomologist, Weyerhaeuser Western Forestry Research Center, Centralia, WA 98531.

Table 1.--Status of cranberry girdler at selected nurseries.

Nursery	Level Outbreak	Year First Reported	Surrounding Habitat
Greeley[1] Olympia, WA	Moderate	1979	Grassland/Pasture
I.F.A.[1] Canby, OR	None	-	Farmland
I.F.A.[1] Toledo, WA	Minor	1979	Woodland
D. L. Phipps Elkton, OR	Severe	1979	Grass/Woodland
Webster[2] Olympia, WA	Minor	1975 ?	Forest
Weyerhaeuser - Aurora Aurora, OR	Minor	1979	Farmland
Weyerhaeuser - Oregon Jefferson, OR	Minor	1974	Farmland/Grass
Weyerhaeuser - Washington Olympia, WA	Severe	1975	Grassland/Pasture
Wind River[3] Carson, WA	None	-	Forest

[1]Pers. Comm., Sally Johnson
[2]Pers. Comm., Bill Fagen
[3]Pers. Comm., Stan Meso

Movement of the moth and laying of eggs is highly dependent on type of vegetation. The moths will not move into areas where there is not suitable habitat for larvae. At the Mima Nursery most insect damage is found in 2+0 beds with a very small amount of damage in transplant beds located adjacent to 2+0 seedlings or in fields that were in 2+0 seedlings the previous year. Damage has been found in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), Noble fir (*Abies procera* Rehd.) and white fir (*Abies concolor* (Gord. & Glend.) Lindl.).

In mid July 1979, we had the opportunity to test a pheromone sex attractant trap specific to the cranberry girdler. By counting the number of male moths caught in the traps, a good indication of the moth population is obtained. The trap used was the Pherocon 2 trap which consists of a waterproof liner board hood over a sticky paper floor. A small rubber septa, containing the sex attractant, is attached to the center of the trap. The traps call male moths by releasing a snythetic substitute for a chemical found in extracts of the abdomen of virgin female moths.

In our test the attractant traps were placed in the following four habitats: 1) grass field, 2) 2+0 DF seedlings, 3) 1+0 DF seedlings, 4) fallow ground. Results confirmed the strong relationship between habitat and population level (Table 2). The very high population levels in grassland surrounding the nursery probably act as an infection source.

Table 2.--Male moth count by habitat type (7/12 - 7/19/79).

Habitat Type	No. Males/Trap	Mean	S.D.
Grassland	26		
	60	41	17.2
	38		
2+0 Seedlings	6		
	10	6	3.5
	3		
1+0 Seedlings	0		
	0	0	0
Fallow	0		
	1	.5	.5

Several methods for control of the insect have been used or are being tested. At the Mima Nursery, we have been using an insecticide program directed at the larvae. This last season we made three directed spray applications of Dursban®[3] at 1#AI/A. The spray was applied with a between the row applicator directed towards the stem of 2+0 seedlings. Sprays were applied in late July, late August and mid September. Results were encouraging. A control plot left unsprayed had 7 percent of seedlings damaged while sprayed seedlings in the same bed had only 0.5 percent.

The use of a directed spray is not the most desirable control method. The spray operation is slow and thus costly. Work on control of the cranberry girdler in grasses has also found that control of the larvae is the least effective method because of the difficulty in getting good penetration of the insecticide to the larvae location (Kamm, 1973). An alternative to larvae control is a spray program directed at the adult moth.

A cooperative test to find effective adult control is being conducted this year at the Phipps Nursery in Oregon and the Weyerhaeuser Washington Forest Nursery, with Jim Kamm and Les McDonough, Agricultural Research Service, USDA. Three insecticides, Diazinon®[4], Sevin®[5], and Pydrin®, are being tested for effectiveness. Large plots, approximately 5 acres each in Washington, have been sprayed with each chemical.

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[3] Common name: Chlorpyrifos
[4] Common name: Diazinon
[5] Common name: Carbaryl

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

The moth population is being monitored within each chemical plot with pheromone traps. Plots will be resprayed when population levels build up.

It is interesting to note that several of the nurseries, which have little or no problem with the cranberry girdler, have other insect pests which require the use of insecticides during the critical period of June and July. For example, at Aurora we know we have cranberry girdler adults but not larvae damage. At Aurora, Diazinon® is used to control the obliquebanded leaf roller (*Choristoneura rosaceana*, Harris) during June and July.

With the availability of a sex attractant specific to the cranberry girdler, another type of control is feasible; namely, mating disruption. The cooperative is also testing this technique. A large quantity of rubber septa containing a high dosage of the sex attractant have been placed in a field. With the very high level of attractant, the male moths have difficulty in locating and mating with females. Pheromone traps have been placed in the mating disruption plot to assess its effects.

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REVIEW OF TECHNIQUES USED TO EVALUATE SEEDLING QUALITY[1]

Annabelle Jaramillo[2]

ABSTRACT

The increasing need for high quality conifer planting stock has increased interest among nursery managers, silviculturists and researchers. Measurement of electrical, chemical and other characteristics that have been used to evaluate planting stock are reviewed.

INTRODUCTION

The increasing need for conifer planting stock of high quality has increased interest among nursery managers, silviculturists, and researchers in improving methods of evaluating the quality of planting stock. Nursery managers want to determine when planting stock is ready to be lifted, stored, or shipped to the planting location. They want to know how well the stock is doing in its new growing environment and to be able to relate its success or failure to cultural or handling practices at the nursery. Rising costs of equipment, chemicals, and payrolls increase a manager's need to use human and fiscal resources more efficiently. Users (silviculturists, reforestation specialists, and others) want to make knowledgeable decisions about when, where, and how to use the planting stock. They need to know the importance of timing cultural practices and of site-matching. They must know whether stock of questionable quality should be used or discarded. Furthermore, nursery managers and users need to understand each other to assure successful reforestation, and knowledge of stock quality is an important part of this communication. Such knowledge and understanding of nursery and field practices can increase the ability of both the nursery manager and user to make responsible decisions.

Researchers have directed much interest toward gathering biological data that can help the nursery manager and user in evaluating stock quality. Sutton (1980) has reviewed some of this research presented at a workshop focusing on evaluation of planting stock quality, held as part of an International Union of Forestry Research Organizations (IUFRO) workshop in New Zealand in 1979.

What is stock quality? Substantial confusion exists on this question among nursery managers, users, and researchers. The term is often used loosely: some use it to describe whether a seedling is dead or alive; others mean whether seedlings are ready to handle (i.e., whether they are in the "right" condition); still others use the term to describe whether or not seedlings are physiologically and morphologically adapted to grow on specific sites. Thus, to <u>improve communication</u> and subsequently

[1]Paper presented at the joint meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Boise, Idaho, August 12-14, 1980.

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increase reforestation success, nursery managers, users, and researchers must clearly define "stock quality"--or at least identify what particular aspect applies for a given use.

Efforts to evaluate planting stock quality have taken many directions. Seedling physiology has been evaluated by physical parameters, such as measurements of plant water status (Cheung et al. 1975; Cleary 1971; Cleary and Zaerr 1979), electrical impedance (Glerum 1970, 1973, 1979; van den Driessche 1969, 1973a, 1976), resistance (Ferguson et al. 1975), and conductivity (Aronsson and Eliasson 1970). Quantitative measures of carbohydrate reserves (Krueger and Trappe 1967) and mineral-nutrient content (Krueger 1967; van den Driessche 1971, 1973a, 1980) have been used to describe chemical parameters. Other tests of seedling quality have included measurements of field survival and laboratory tests of survival potential (Jenkinson and Nelson 1978; Askren and Hermann 1979; Hermann and Lavender 1979).

In this paper, I will review several methods currently being used to evaluate quality of conifer planting stock. I am omitting evaluation of stock quality by morphological characteristics and the matching of stock to specific planting sites because of time limitations. Instead, I will concentrate on measures of seedling health and vigor.

DESCRIPTIONS

Tests or techniques for estimating seedling quality can be used at different levels of refinement; some may simply tell us whether seedlings are dead or alive. In areas subject to heavy frosts, estimating cold hardiness in seedlings is useful. Estimating levels of dormancy can assist the nursery manager in choosing the best lifting times. Some tests take weeks to provide information, but others can give immediate answers. No one test can tell us all we may wish to know about the seedling. We must be cautious when we use instruments as predictors of seedling quality. For example, a seedling can be dead and still have low moisture stress. We should know about differences in values that occur at different times and how to interpret these data.

ELECTRICAL MEASUREMENT OF PLANT TISSUES

Cell-wall resistance, cytoplasm resistance, and cell-membrane resistance and capacitance are components of electrical circuits in plants. Changes in the physiological status of a plant can effect changes in these components. Because electrical resistance in plant tissues is ionic rather than electronic, measures of these characteristics in plants must be interpreted carefully; variation can be influenced by factors such as seedling diameter, temperature, and moisture. The following techniques have been suggested as tools that nursery managers can use to evaluate the physiological status of seedlings.

Electrical impedance. Electrical impedance is measured by passing electrical current through a four-electrode probe inserted into plant tissue, usually at two frequencies, and expressed as a ratio. Measurements of electrical impedance have been used in studies of frost hardiness (Aronsson and Eliasson 1970; Glerum 1973; van den Driessche 1969, 1973b, 1976). In these studies, impedance measurements were made before and after plant tissues were subjected to freezing temperatures. Frost hardiness was determined by the extent of injury to the tissues, which correlated with a significant decrease in electrical impedance. Although electrical impedance measurements are nondestructive and easy to make, they are not easily translated into physiological condition of plant tissue. Electrical impedance measurements are affected by stem diameter, temperature, and tissue moisture content.

Glerum (1979) indicated that impedance measurements are of limited use in studies of water potential. Kitching (1966) also found electrical impedance measurements were not useful as an index of moisture stress. Measurements of electrical impedance appear to be promising in some areas of study, but because they vary by species and location they will be useful only when extensively studied and calibrated locally (i.e., in each nursery) for each species grown. A IUFRO project group focusing on nursery problems is currently suggesting standardization of electrical impedence curves for each nursery.

Oscilloscope square-wave apparatus. The application of a square-wave electrical pulse withoug seedling stem tissue and observation of trace forms on an oscilloscope (fig. 1) has been suggested as a tool to evaluate the condition of plant tissue

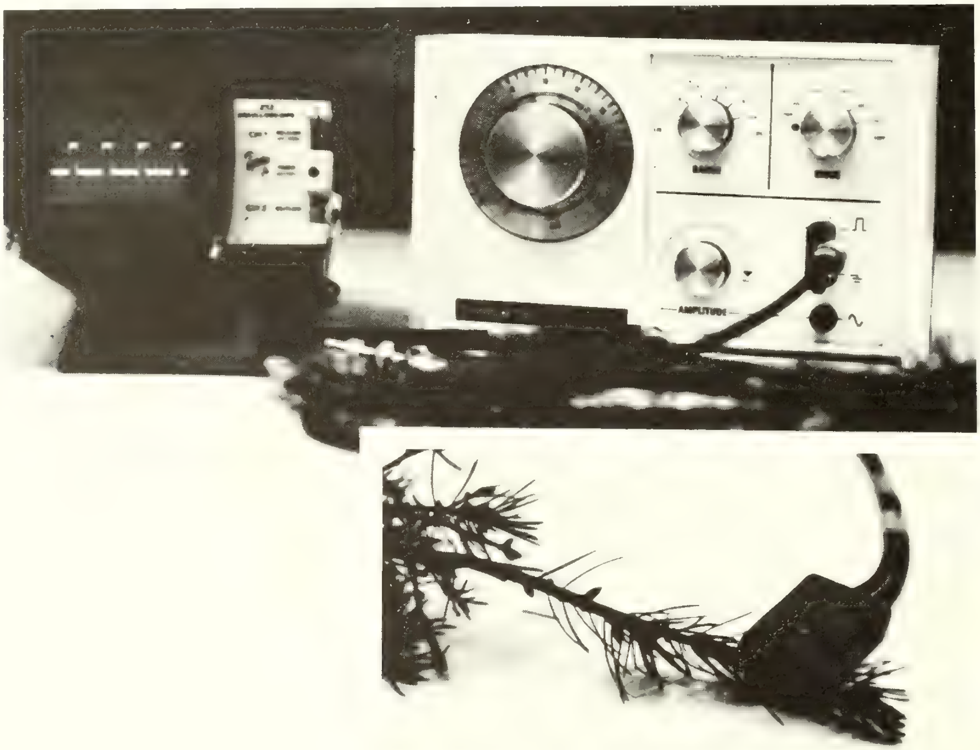

Figure 1. Oscilloscope/square-wave apparatus. Insert: electrode from oscilloscope/square-wave apparatus in seedling terminal.

(Zaerr 1972; Ferguson et al. 1975). Zaerr exposed plant tissues to freezing, steaming, and herbicides. He found that trace forms of healthy tissues differed from those of dead tissues. Although the species being observed had their own characteristic trace forms, "...differences in shape of curve for live and dead tissues of a given species were consistent." Ferguson and others (1975) noted changes in trace form (Fig. 2) of several species at different times of the year and suggested that the forms could be used to determine dormancy. These changes appeared to be related to the growth activity or dormancy of their samples. Dormancy was "measured" by time of year and not actually determined by growth tests, however. In a previous paper (Jaramillo 1978), I reported a lack of correlation between "dormant" trace forms and cold hardiness of Douglas-fir seedlings. I found that visual observation of changes in trace form could not be used as indicators of cold hardiness. Askren and Hermann (1979) took voltage measurements at three constant points of the trace--high-frequency

(HFV), mid-frequency voltage (MFV), and low-frequency voltage (LFV)--and used ratios of these measurements to typify trace forms. These ratios were used in tests of seedling survival potential. They found that "...trace character apparently does not indicate vigor as such, and thus is poorly suited for predicting survival potential." In her investigation of the relation of electrical impedance to vegetative maturity and dormancy in red-osier dogwood, Parmelee (1979) ruled out the oscilloscope/square-wave technique because of the difficulties encountered with interpretation and reliability of the square wave. Standard wave-traces would have to be established for each plant species because each tends to exhibit its own characteristic traces. In addition, slight movement of a twig in which the probes are inserted creates differences in wave form. These limitations cast doubt on a practical use of square-wave forms as visual indicators of plant physiological condition.

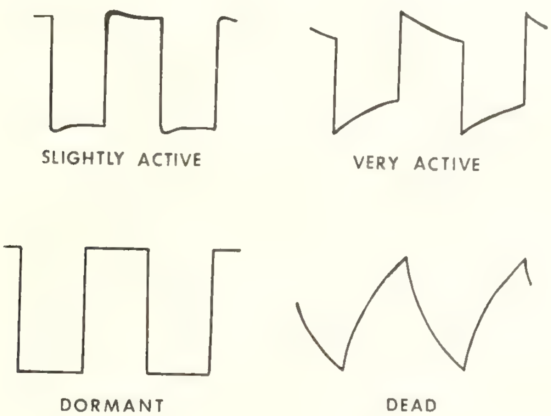

Figure 2. Square-wave trace forms indicating growth condition (Ferguson et al. 1975).

Dormancy meter. A solid-state dormancy meter (Fig. 3) has been designed for determining physiological activity of nursery stock, as a less costly substitute for the oscilloscope/square-wave apparatus. The Missoula Equipment Development Center's engineers have determined "...that an instrument which measures the ratio of voltage at 500 hertz and at 10 kilohertz gives basically the same performance..." as the oscilloscope/square-wave apparatus[3]. Preliminary tests[4] that I made comparing dormancy meter readings with square-wave trace form showed little or no correlation between the two instruments. I did not compare meter readings with actual seedling physiological status. A more thorough investigation of this relationship should be made before the instrument is recommended for operational use.

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[3]February 1977. Report 7741 2505. Equipment Development Center, USDA-FS, Fort Missoula, Missoula, Montana.

[4]Jaramillo, Annabelle E. 1978, 1979. Office Reports: Comparison of Oscilloscope/Square Wave Apparatus and the MEDC Dormancy Meter.

Figure 3. Dormancy meter designed by Missoula Equipment Development Center, USDA Forest Service.

PHYSIOLOGICAL WATER STATUS

Energy status of water in plants results from transpiration, evaporation, and other factors. Water status in a soil-plant continuum is dynamic, and the water is rarely in equilibrium with that in surrounding areas. Because the process is dynamic, measurements must be interpreted carefully by someone knowledgeable in plant-water relations.

Because plant responses to water stress are closely related to the energy required to remove a unit of water from soil, instruments used to measure soil-water status have been investigated as possible tools to estimate plant-water status. I will describe only techniques that measure water inside plants, however.

Psychrometric measure of water potential. Water potential of a small sample of plant tissue is measured by condensing water from the atmosphere in a psychrometer chamber, in which the tissue is placed, on to a measuring junction (thermocouple). Measurement of output voltage (on a microvoltmeter connected to a psychrometer) across the thermocouple is a function of the water potential in the psychrometer and ambient temperature. Stein and Jaramillo[5] tested water potential of Douglas-fir needles and found that the psychrometric measurements were too variable to be used as indicators of seedling quality. The sensitivity of the psychrometer (fig. 4) to fluctuating ambient temperatures, the lengthy periods needed to calibrate the instrument and make observations, and the need to establish standard curves for the tissues being tested make it highly impractical as a predictive tool.

[5]Stein and Jaramillo, unpublished data, on file at FSL.

Figure 4. Equipment needed for water-potential studies. Psychrometer chamber apparatus is connected to a microvoltmeter. A paper disc, saturated in tissue water extracted by maceration is inserted in the psychrometer chamber. The equipment is calibrated by known standards.

Freezing-point depression. Carey and Fisher (1969) and Fisher (1972) have described a small, portable instrument that measures the freezing-point depression of plant tissue. It consists of a small freezing chamber mounted on the cold side of a Peltier battery. They suggest that "...freezing-point depression measured immediately after ice crystals begin to form in plant tissue in the field could give on-the-spot estimates of plant water stress." This has advantages over the psychrometric method because it is less time consuming, less expensive, and can be used on more types of plant tissue. The practicality of both water-potential and freezing-point depression measures need to be investigated more intensely for conifer seedling tissues before they can be suggested as useful tools for evaluating stock quality.

Pressure-chamber (pressure-bomb) technique. At a recent IUFRO Conference, Cleary and Zaerr (1979) described the pressure-chamber technique used to evaluate plant water status. In the instrument (fig. 5), the negative potential in the xylem of the plant is balanced with the positive pressure of a chamber. A sample is cut from a seedling and placed in the chamber with the cut end exposed through the chamber cover. Pressure is slowly increased in the chamber until water is forced back to the cut surface. This pressure is an estimate of plant moisture stress (PMS) in bars. Drawbacks of the technique are that values of zero stress levels are not obtainable and that it requires compressed gas, which can be potentially dangerous if not used carefully. The pressure chamber technique is relatively fast and easy and gives good estimates of seedling water status. But it should not be the only tool used to determine stock quality, because water status does not always tell the whole story. The pressure chamber is currently being used at many nurseries in the Pacific Northwest for regulating irrigation schedules and determining when stress is too high for lifting and handling. Many silviculturists also use pressure chambers for checking stock quality in the field.

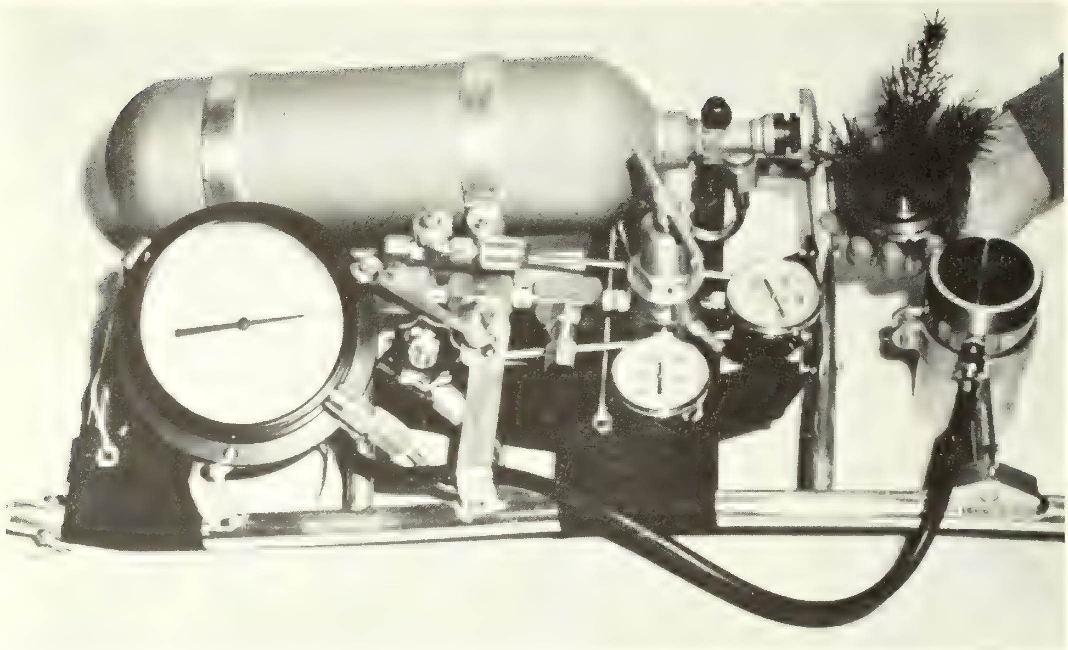

Figure 5. Pressure-chamber apparatus used to measure moisture stress using compressed gas.

Hydraulic Press. A hydraulic press has been developed (fig. 6) for measuring leaf-water stress and soil-water content. Measured hydraulic pressure beneath a flexible membrane is used to press a leaf or other plant tissue against a plexiglass window. As pressure is applied, water appears at the cut edge of the stem or leaf. Additional pressure causes changes in leaf color. Water stress is characterized by the pressure required to produce the color change accompanied by continual water excretion. Advantages are that the instrument can make measurements rapidly and that it does not require a compressed gas supply. Disadvantages reported by Cleary and Zaerr (1979) are: the end point is indefinite; precision is low; the instrument must be calibrated with a pressure chamber; foliage of different ages gives different results; and a very large sample size is required for acceptable accuracy. Until further data on the hydraulic press are reported, operational use of the technique is questionable.

Figure 6. Hydraulic press used to measure moisture stress.

CHEMICAL CHARACTERISTICS OF PLANT TISSUES.

Foliage nutrient content and carbohydrate reserves have been the most commonly studied chemical characteristics of seedlings. Visual clues--such as needle chlorosis, needle curl, and stunted growth--can tell us that some mineral element vital for growth is deficient. Knowledge of the mineral nutrient status of seedlings can tell us whether to apply or delete fertilizers to insure optimum growth of seedlings. Similarly, knowing something about carbohydrate levels at different times of the year helps establish handling practices that take advantage of carbohydrate reserves within the seedlings. We must know how to interpret the data and how they relate to planting stock quality, however.

Foliage nutrient content. Foliage nutrient content has been suggested as a predictor of seedling survival. Wakely (1949) suggested that evidence of a direct relation "...between chemical (nutrient) differences in seedlings..." and "...differences in survival and growth after planting..." was needed to establish foliage nutrient content as a predictor. Switzer and Nelson (1963) found that for 1+0 loblolly pine seedlings, a linear relation existed between height at 3 years in the field and foliar nitrogen content at lifting. Regression analyses indicated, however, that field survival could not be predicted by foliage nutrient content. Heiner and Lavender (1972) found that foliar calcium/potassium ratios of 2+0 Douglas-fir seedlings did not correlate with field survival. In their investigation of 1+0 seedlings of several pine species, Gilmore and Kahler (1965) found no relation between field survival and foliage contents of nitrogen, phosphorus, or potassium. Although nursery fertilization does enhance seedling growth, foliage nutrient content at time of lifting has not been useful as a predictor of field survival. In addition to a lack of correlative data, assessment of foliage nutrient content is further hampered by the need for specialized equipment, a skilled investigator, and lengthy lapse times for results. Although many studies have been aimed at determining desirable nutrient levels within seedlings, no standardization of these levels and few correlations with field performance have been made. These factors limit the use of nutrient status as a predictor of stock quality.

Carbohydrate reserves. Krueger and Trappe (1967) observed substantial seasonal changes in carbohydrate concentrations of Douglas-fir seedlings at the USDA Forest Service Wind River Nursery. In the fall when top growth stopped, sugar reserves gradually increased. Maximum concentrations occurred with the coldest weather. A late winter decrease in sugar concentrations coincided with an increase in starch concentrations. They suggested that information on carbohydrate reserves might be used in selecting appropriate times to handle planting stock, which might improve survival in the field. Like mineral nutrient content, carbohydrate reserve data are useful only if we have standards for comparison. Further work is needed before information on carbohydrate reserves in conifer seedlings can be used as a predictive tool. The need for specialized equipment, skilled personnel, and lapse times for results also makes operational use doubtful.

GROWTH-EVALUATION TECHNIQUES

Jenkinson and Nelson (1978) reported the use of root-growth capacity (RGC) of Douglas-fir seedlings as a predictor of field survival. RGC, previously termed root-regenerating potential (RRP), is the seedling's ability to initiate new roots and elongate existing roots under conditions favorable for growth. RGC is estimated by measuring new root growth in controlled favorable environments for a specific period. Jenkinson and Nelson (1978) found that field survival was associated with RGC values. RGC appears promising as one method of evaluating quality of planting stock. Additional standards of RGC for different species, seed sources, and nurseries must be established and correlated with field performance, however.

Hermann and Lavender (1979) encouraged testing of seedling vigor as a measure of stock quality. This requires maintaining seedlings under constant conditions in a growth room and observing bud flush and survival. A random sample is selected from a nursery lot for testing. Half of the sample is kept as a control (not stressed), the other half is stressed by exposing bare roots and shoots to 90°F and relative humidity of 30 percent for 15 minutes just before potting the seedlings. (This stress testing can be varied according to the intended planting site.) All seedlings are potted and then kept for at least 4 weeks at 70°F (±5°F) with a 16-hour photoperiod of 500 foot candles. In 4-6 weeks, bud flush can be used as an indicator of vigor. An additional sample should be monitored in the field. Hermann and Lavender suggest that if a lot is deemed satisfactory in vigor tests but has poor survival in the field, seedlings may not have been properly handled during storage, transport, or planting. If field survival is much better than in the growth room, the procedures for that particular vigor test may have been conducted improperly. Poor survival in the field and the growth room can indicate a problem in the nursery environment or cultural practices.

DISCUSSION

I believe the most successful evaluations of planting stock now available are tests of seedling vigor and field survival. Although they do require time, they integrate all the various conditions and quality factors and give us information that can be useful for suggesting future nursery and planting practices. We can include other types of testing to determine specific characteristics and to search for more rapid determiners of overall seedling quality.

Coniferous tree seedlings--like all plants--are complex systems in which many internal processes occur and interact. These systems are affected by the environment in which the seedlings grow. A multitude of studies is directed at unraveling and understanding these complex systems. The techniques I have reviewed here are a small part of these investigations. Measures of the physical properties of seedlings have been attempted through studies of electrical impedance, resistance and capacitance of seedling cells and tissues, and plant moisture status. Analyses of foliage nutrient content and carbohydrate reserves have given us much information about the biochemical nature of seedlings. Tests of growth and seedling vigor are important for evaluating stock quality.

We should not depend on one method alone to tell us everything we want to know about seedlings. We have to look at what a combination of methods tell us and continue to look for new tools to evaluate planting stock quality. My fantasy is to have, some day, a tricorder (the little black box carried by Mr. Spock, science officer on the Starship Enterprise) to carry into a greenhouse or out to the nursery bed and have it tell me, at the push of a button, all there is to know about a seedling and its potential. In reality, we do not have such a single tool--and probably never will. But the tools we do have can be used separately or jointly to gather the information we need about planting stock to improve our reforestation efforts.

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TECHNIQUES OF QUALITY CONTROL FOR SEEDLING LIFTING OPERATIONS[1]

John H. Hinz[2]

ABSTRACT

Describes methods and rational for monitoring seedling quality during lifting operations at a Southern Idaho forest nursery. Includes descriptions of methods for measuring dormancy and plant moisture stress and provisions for protection of stock during lifting and transport to packing shed.

INTRODUCTION

Since the reforestation process is especially sensitive to any mistakes made in the rearing or handling of planting stock, the prudent nursery manager is well advised to monitor the effects of his/her practices upon the quality of the finished product. Each phase of nursery operation offers its own unique set of problems and opportunities with regard to quality control. This paper describes the quality control techniques used at a Southern Idaho forest nursery during a particularly critical phase of the reforestation process: seedling lifting.

Built in 1960 as the U.S. Forest Service nursery for the Intermountain Region (R-4), Lucky Peak provides the majority of the seedlings used for reforestation projects in that region as well as contributing to the efforts of the Southwest Region (R-3), the Pacific Northwest Region (R-6) and several other agencies, including BLM, and Idaho Fish and Game. Production in recent years has been on the order of 9 to 11 million 2-0 seedlings. With the reduction in reforestation backlogs, and with the nursery at Albuquerque producing seedlings for R-3, Lucky Peak production will probably stabilize at somewhere between 6 and 8 million seedlings per year. Species produced include most of the common western conifers, particularly lodgepole pine, Douglas-fir, and ponderosa pine, as well as several species of native shrubs. Most seedlings are spring-lifted, though a small fall lift (1-2 million seedlings) is usually conducted.

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[1]Paper presented at joint meeting of Intermountain Nurseryman's Association and Western Forest Nursery Council, Boise, Idaho, August 12-14, 1980.

[2]Forester, U.S.D.A., Forest Service, Boise National Forest, Lucky Peak Nursery, Boise, Idaho.

PROCEDURES

Lifting is done primarily with contract labor and proceeds as follows: Seedlings are undercut to a depth of about twelve inches with a standard tree-lifting blade drawn by a crawler tractor. This is followed by a wheel tractor drawn Egedal lifter/ shaker which vibrates to loosen the seedlings in the soil. The lifting crew then lifts the seedlings by hand, shaking the soil free from the roots and placing them immediately into plastic boxes layered with wet burlap. As soon as possible these boxes are loaded onto trailers and taken to the seedling coolers, where they are segregated by source and stored at 34°F until they can be graded and packed.

Quality controls associated with the lifting operation can be seperated into two general categories:

1. Monitoring the physiological condition of the seedlings.
2. Protection from injury.

The primary concerns with respect to physiological condition of seedlings are dormancy and plant moisture stress. The conventional wisdom in reforestation is that, other things being equal, seedlings which are lifted during their dormant period are better able to withstand the shock of lifting, packing, storing, and planting than are seedlings which are lifted during a period of activity.

At Lucky Peak Nursery seedlings usually enter dormancy in early to mid-November, breaking dormancy anywhere from late February to mid-March. Ideally, lifting would be done sometime between these two dates. Unfortunately, Lucky Peak is situated such that, very shortly after the seedlings enter dormancy the soil freezes, preventing lifting. Usually it remains frozen until just a few days prior to the time when the seedlings break dormancy in the spring. Thus, if seedlings are to be lifted while dormant, the lifting must be done in a very short period of time.

Because of this situation, seedling dormancy is monitored very closely as the season for fall lifting approaches so that lifting can begin as soon as the seedlings are dormant. For the past several years a portable oscilloscope and square wave generator has been used to determine the degree of dormancy within the seedlings. This technique (Ferguson, Ryker, and Ballard, 1975) requires the interpretation of a square wave pattern on an oscilloscope screen which, having been transmitted through the seedling with a needle-like probe, changes shape in response to the physiological activity within the plant. Though its validity as a measure of dormancy has not been universally accepted by plant physiologists, the oscilloscope technique provides a useful guide to the practicing nursery manager in deciding when to start lifting operations.

Since 1979 we have also been using the Missoula Equipment Development Center dormancy meter as a supplement to the oscilloscope. This instrument utilizes a probe similar to that on the oscilloscope, but has the advantage that it gives numerical readouts supplemented by lights indicating "Dead", "Dormant", or "Active", so that interpretation of wave patterns is not necessary. Being neither an electrical engineer nor a plant physiologist I am ill-equipped to comment upon the validity of this device in an absolute sense, however, I have observed that readings taken with the dormancy meter generally agree with oscilloscope readings taken on the same plants.

In addition to using the oscilloscope and dormancy meter to determine when to commence fall lifting operations, these instruments are also used to monitor the state of seedling dormancy during the spring lift. While an indication that seedlings are breaking dormancy during the spring lift will not allow us to lift them any faster (this is usually controlled by field and weather conditions), such information is useful in that it can tell a receiving forest that a given lot of seedlings may be particularly sensitive to mishandling.

Plant moisture stress is also closely monitored during lifting operations. Though a pressure bomb is available at Lucky Peak, it is used for testing seedlings during the packing operation and just prior to shipping. Field testing for PMS is done using the Model J-14 press, manufactured by Campbell Scientific, Inc., Logan, Utah. These measurements are taken on each seedlot prior to undercutting, after undercutting, after lifting, and as the seedlings are placed in cold storage prior to packing. This proceedure allows us to determine if mistreatment of stock resulting in increased plant moisture stress has occurred at any point in the lifting operation. We consider any PMS reading above 10 atmospheres to be indicative of problems. Using this information we can correct any systematic mistreatment of the stock and be aware of possible damage to any seedlot.

That the J-14 press provides readings exactly equivalent to those provided by the pressure bomb is not a universally accepted fact. Our quality control people who use both instruments side-by-side to test seedlings during the packing operation have consistently obtained very similar readings. A random sample of ten seedlots tested with both instruments (ten readings taken per seedlot with each instrument for each of ten seedlots) over the past two packing seasons by an assortment of individuals yielded a correlation coefficient of .88. However, midday readings taken on growing seedlings in the field during the summer of 1980 have shown that, when the pressure bomb readings have started to approach 15 atmospheres, readings with the J-14 have been significantly lower, reading about 7-9 atmospheres. Though I do not yet have enough data to draw any firm conclusions, if this relationship proves to be consistent, our use and interpretation of the J-14 press will have to be modified.

Besides monitoring the physiological condition of seedlings, every effort is made to protect them from injury during the process of lifting and transport to the storage coolers. As most lifting is done with contract labor, several contract clauses have been developed to protect the seedlings from careless mishandling. Under the contract, lifters can be fined for any of the following infractions:

1. Lifting less than two handsful.
2. Excess soil on seedling roots.
3. Abuse of seedlings to remove excess soil.
4. Failure to properly cover lifted seedlings.
5. Piling seedlings on the ground.
6. Exposing roots to the air for longer than 20 seconds.
7. Leaving any seedlings in beds.
8. Walking on seedlings.

The contract outlines specific proceedures for lifting and provides plenty of leeway for the nursery to halt operations if field or weather conditions become detrimental to the condition of the seedlings.

Lucky Peak Nursery has several inherent characteristics which inhibit quality during lifting. In addition to the limited time period when suitable lifting conditions coincide with seedling dormancy, foremost among these is the soil, which has a very high clay content. This causes excessive stripping of fine roots, a situation which has been at least partially alleviated by the use of the Egedal lifter/shaker. The fine textured soil is also very sensitive to conditions of high soil moisture, draining very slowly and becoming almost like glue when wet.

At the least this results in a slowdown of the lifting operation, frequently to the extent that dormancy is broken in the spring, accompanied by much stuck equipment and a general gnashing of teeth among all concerned. Careful planning combined with having a well-trained and resourceful field crew have helped us work around this problem. Half-track units on our lifting tractor and a crawler tractor-mounted winch have also demonstrated their value several times over.

There is sometimes a slight delay in bringing the freshly-lifted stock from the field to the storage coolers. This is caused by a particularly fast lifting crew or by field conditions which prevent the rapid loading of seedling boxes onto trailers. This is potentially a very serious problem as the seedlings may, even though they are covered by wet burlap, start to heat up, causing moisture stress. Construction of additional trailers for hauling seedlings from the field and the rental of extra tractors during the lifting season has reduced this problem. The purchase of a tractor-mounted forklift to load boxed seedlings onto the trailers in the field is expected to speed up their transportation.

Another bottleneck occasionally develops when the amount of freshly-lifted seedlings arriving at the cooler exceeds the capacity of the coolers. With the usual pressure to lift seedlings while they are dormant, it isn't possible to simply shut down the lifting until more cooler space can be made available by packing and shipping the seedlings. While many things have been attempted to alleviate this situation, including placing seedling boxes under sprinklers on the loading dock, the long-term answer is additional cooler space. Requests for funds to construct an additional cooler in fiscal year 1980 have been denied.

DISCUSSION

Quality control efforts at Lucky Peak Nursery do not begin and end with the proceedures outlined here. Plant moisture stress, shoot/root ratio, height, caliper, and dormancy tests are conducted during the packing operation. Storage temperatures are monitored continually. Indeed, every phase of our work from seed processing to shipping has some effect upon the quality of the stock we produce. We are well aware of this fact and make every effort to learn the consequences of our actions and to modify them where necessary.

Still, improvements can be made. A comprehensive study of dormancy, plant moisture stress, and the instruments used to measure them would be welcomed in order to clarify the role of these phenomena in reforestation and to reduce confusion as to their measurement. Growth chamber or root growth capacity tests of each seedlot might also be desirable. As our ability to use existing knowledge about successful seedling culture and reforestation techniques improves, and as new knowledge become available, the quality of our product will surely improve.

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QUALITY CONTROL

TREE PROCESSING OPERATION[1]

David W. Dutton[2]

ABSTRACT

Discusses some methods and procedures for monitoring seedling quality control during tree processing operations at U.S. Forest Service, Wind River Nursery, Carson, Washington. Describes why and how the quality training of people and good communication with the field improves stock quality and thus field survival.

INTRODUCTION

The aim of nursery stock quality controls is to provide stock which will survive, become established, and produce vigorously growing plantations.

I believe that at Wind River Nursery we have attained high quality control through the continuous training of our people in the handling and care of tree stock. This is accomplished by annual orientation and training sessions for all temporary employees.

They have responded with a dedication, interest, and hard work that is truly amazing and heart warming to see. We believe that growing quality seedlings is really not a big secret. It is the application of available and tested knowledge to a management system. It's the attention to a constant stream of daily details that many take for granted. It's the constant anticipation, vigilance and careful handling every step of the tree growing process - from the time the soils analysis is made, the seed is sown to the planting, and eventually to the survival of a high quality seedling. When you give people increased responsibliity and greater opportunities in seedling production, attention to detail comes much easier.

COMMUNICATION AND DOCUMENTATION

We stress open communication with our customers. We try to eliminate any surprises. One way to do this is through field visits to our nursery. We have been invited to most Forests to view successes as well as problems. We know these

1 Paper presented at Intermountain Nurseryman's Association, Western Forest Nursery Council, Boise, Idaho, August 14, 1980.

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visitations are successful as we now are having far fewer problems in meeting their needs. Also, we produce a stock catalog. This has helped keep everyone informed of what our seedlings look like and their average size. Every phase of our operations is governed and documented by a list of procedures. These are kept in a "Brain Book" and continuously updated.

Chairman, Dick Thatcher, has asked me to tell you about our quality control in seedling processing at Wind River Nursery. I thank him for asking us to share with you. I can best tell you in this short time by showing a few slides of some of the various steps we take. I will highlight our seedling handling from the time the trees leave the beds until they reach the requesting unit. I will now begin by introducing you to our nursery with a few general slides of the area.

LOCATION

Wind River Nursery is located in the State of Washington ten miles north of the mighty Columbia River and Bonneville Dam and about fifty miles east of Vancouver, Washington and Portland, Oregon. You may be interested in the fact we are only about 25 miles SE of the now famous and unpredictable Mt. St. Helens.

WIND RIVER NURSERY

These are overall views of our nursery fields and our landmark, known as "Bunker Hill." We have produced over 30 million seedlings annually the past seven years. This consists of abqut 55% Douglas-fir, 25% true firs (mainly Noble). The remainder is pines, spruces, and cedars. We sow for about 14-15 species annually.

PROCESSING FACILITY

These are views of our new Processing Facility constructed in 1977 at a cost of about 2 1/2 million dollars. We estimate this building will pay for itself in 15 years if regional seedling survival increases only 3%. This building contains three main sections: the employee wing, the main packing room, and six storage coolers with a capacity of about fifteen million seedlings. This facility was designed with our weather in mind. When the seedlings are dormant and can be lifted we lift all we can. When the weather is bad we stay inside and pack them.

Quality control in tree processing begins with our lifting priorities. They are normally as follows:

1. Cleanest lifting possible.
2. To supply field units that are ready to plant.
3. Lift the greatest number of trees at the most effective cost.
4. Lift those seedlings most likely to break dormancy earliest.
5. Lift those seedlings most likely to be in storage over three months.
6. Lift those areas last where the soils are protected from warming up due to seedbed arrangement, snow cover or shade.

SEEDLINGS LEAVING FIELD

We dedicate ourselves to getting the seedlings into cold storage as rapidly as possible, especially on days with the plant moisture stress (PMS) approaching the marginal levels. We shut down at a plant moisture stress reading of 12-15. This only occurs one or two days during the lifting season. You need to be ready and able to take action immediately.

We have found that watering the seedlings has a cooling effect and holds down the plant moisture stress.

Each seed lot is assigned a number. All seedling boxes in that lot are numbered after the box is filled with seedlings in the field. This is one of the many steps taken to assure individual lots are not mixed up and the lot qualifies to be certified at a designated level.

SEEDLINGS ARRIVING AT PROCESSING BUILDING

This series of slides is taken at our unloading area. These two coolers are designated as pre-coolers where the unpacked seedlings are stored before being processed.

TESTS

Samples for testing are taken from each lot as it arrives from the field.

LABORATORY

This is an overall view of our laboratory. Here you observe two instruments used to measure plant moisture stress in every seedlot. Our laboratory is located in close proximity to the unloading area, coolers and processing room. Size classification is taken. Also, in our laboratory the processing supervisor can examine tree quality to see if any specific grading guidelines are required.

PLANT MOISTURE STRESS TEST EQUIPMENT

We use the J-14 Pressure Jack and Pressure Bomb to measure moisture stress in our seedlings. We have also participated in the Oregon State Forest Research Laboratory Program of testing to determine the physiological soundness of seedlings prior to outplanting.

TESTING FOR DORMANCY

We have used the dormancy meter mainly in the field in fall and feel it gives us a quick indicator of approaching dormancy. We also have used the square-wave oscilloscope. Our problem is the great cost and care to keep the instrument in operation.

(What we need is Russ Ryker around to keep it running).

SHOOT-ROOT RATIO TEST

The shoot-root ratio test is a volumetric measure of water displacement of both the top and the roots. Here is a shoot-root ratio of about 1/1 on a Douglas-fir. This is an excellent ratio for Pacific Northwest planting sites.

PROCESSING ROOM

This shows the general layout of our processing and grading room. We have eight tables which were running this particular day. Our daily production is 1 million seedlings in an eight hour day.

INFORMATION BOARD

Each grading table has this board mounted on the wall with grading specifications and any special instructions. One quality control person assigned to each table is responsible for recording correct grading specifications on the board before each lot is graded. Each grader is required to read this board and thoroughly understand the "specs" before beginning work. The main requirement for a grader is to know minimum shoot and root lengths, seedling caliper and how to cull for damage. Also, the pruner needs to know pruning lengths.

GRADING AND COUNTING SEEDLINGS

This series of slides shows our overall grading and counting process. A grading table consists of twelve sorters, one buncher, one bander and a packer. Persons count seedlings in groups of five or ten. We have had requests for double sorts. We can also combine seedling species if desired. The next slide shows one of our happy nursery employees. Note the table arrangement, whereby one side faces the other. The next two slides show counting, grading and placing seedlings on a designated target line, one inch above the top lateral root. This aids in a higher quality root pruning job. This shows a watering device we can use if seedlings need washing off or appear to be drying out. One table can process an average of 130 thousand seedlings daily.

TUNNEL

A tunnel runs the length of our processing building. It is used to dispose of culls, soil, debris and excess water. Between each seed lot culls are scraped into the tunnel to avoid seed lot contamination. This definitely is a plus for quality control and seedling certification. Also, the room is kept cleaner and thus safer. When you have this condition the employees are happier and efficiency increases.

BUNCHING AND ROOT PRUNING

This person bunches the graded seedlings into bunches of 25 or 50, depending on the size. Then the seedling roots are pruned to the requested length. This is an extremely important step, because in order to eliminate contract problems the correct root length is needed.

GRADING TABLE AT BREAK

All seedling boxes are covered during break periods to prevent drying out. Also, we try not to give any seedling a total of one hour accumulated time out of cold storage. The bottom line conveyor carries the full boxes in, the top line carries empty boxes out. Empty cardboard boxes are then broken down and returned to the field. A box handler does this job for two tables.

MARKING SEEDLING BAGS

At each grading table quality control records are kept. We mark all bags with table number and lot numbers, the seed lot description, lift and pack dates and number of seedlings in the bag. When the bag is shipped, we also mark the shipping date.

BAGGING AND QUALITY CHECKS CONTROL

Each table has a leader who is also the quality control person. The quality control person checks many things according to established procedures. We need to make sure specifications are being met and we are shipping the proper number of seedlings.

BAG CLOSING

We use one sewing machine to close the bags for two tables. Our seedling bag is three layers with a waxed bottom over stitching. We try to keep bag weight under forty pounds for easier handling. Normally a bag holds about 500 Douglas-fir and 800-1,000 true fir. Good storage conditions have eliminated the need for packing media in most situations in Pacific Northwest Region nurseries.

PACKED TREES TO STORAGE

Seedlings come from the field on pallets in boxes and processed trees are stored on the same pallets. Note seedling certification tag on bag.

PACKED AND SHIPPING RECORDS

Numerous warehousing records are kept to insure we know where the trees are stored, how many were packed, how many were shipped, and when and how this was all done.

An earlier record of each seed lot information was kept on a McBee Card. Then we refined the system and now use what we call a seed lot information card. This card gives much information as to sowing, inventory and cultural practices. Another sheet which we call the silvicultural sheet originates when the order is received and is sent to the receiving party upon seedling shipment. It tells us things such as dormancy, temperatures, and humidities, and plant moisture stress, equipment used, time and day lifted. It can also give any special instructions. This helps us adjust operations accordingly. This sheet also has a section that the field can fill out upon receiving the trees. This record has helped us often identifying why a particular problem occured and in other communications with our customers.

TREE STORAGE AND MECHANICAL ROOM

Temperatures and humidities are constantly monitored and documented to avoid any large fluctuations in the storage rooms. Fluctuations are only about one degree for temperature and 5% for relative humidity. I feel that our excellent cold storage facilities are a big factor in our increased survival.

SHIPPING

The seedlings are taken out of storage and loaded into a truck. Note the large loading dock and person checking the seed lot and numbers being loaded. We try to schedule most deliveries so that delivery is made in one day. Temperatures are monitored by thermographs placed among the bags. Our people are instructed to handle the bags as if they were eggs.

DELIVERY

Presently we deliver about 20 million seedlings or 2/3 of of annual production to our customers in Oregon and Washington. All Forest Service seedlings are shipped in refrigerated vans. With our present mileage restrictions we are being forced to seek other means to deliver our seedlings.

SEEDLING CERTIFICATION

Every step of our seedling processing is also monitored by our seed certification agency, which operates both in Oregon and Washington.

CONCLUSION

Now if St. Helens cooperates and doesn't cover us with a foot of ash we hope to continue producing quality seedlings for the Pacific Northwest Region. We invite you to visit us.

In conlusion, I say to you that we can afford to take most every precaution in seedling care and handling that is known. All costs are continuously going up and we can't afford to plant a low quality seedling. I believe the "proof is in the puddin'."

Our Region's field survival has increased dramatically. The key to this increase is management's ability to provide us with equipment and facilities. Another key is communication and documentation for our customers, the Ranger District people. Last, but not least, is our ability to handle seedlings in such a manner that vigor is not diminished. All this is accomplished through procedures and communication with our own people.

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REQUIREMENTS FOR QUALITY IRRIGATION[1]

Marvin N. Shearer[2]

ABSTRACT

Quality irrigation requires that irrigations be applied at the right time, at the right rate, in the right amount and uniformly. Uniform application and appropriate application rates are obtained through the proper selection of nozzle diameter, sprinkler spacing, and pressure.

INTRODUCTION

Budgets and competitive bidding, rather than quality performance, dominates the lesign of sprinkler systems today. But that small amount of money saved is dwarfed iany times as losses pile up on losses year after year from the effects of less than idequate design.

Some words in our vocabulary tend to become useful primarily for their value as hetoric for they have the ability to charm and influence. "Efficiency" is one of hese; "quality" is another. Unless we give definition to these words, they can have ll kinds of meanings, or none at all.

Let me tell you what I mean by quality irrigation. It is irrigation that occurs t the right time, it is applied in the right amount, it is applied at a rate so hat the water penetrates into the soil rather than ponding on the surface or running ff, <u>and</u> it is applied uniformly.

Recognition of the importance of uniform water distribution and procedures for btaining it are two of the most prominent omissions in sprinkler system design and rocurement, and this is the first subject I wish to talk about today.

UNIFORM WATER APPLICATION

Application Efficiency

We can achieve high application efficiency and at the same time do a totally uncceptable job of irrigation. Let me illustrate.

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[1]Paper presented at Joint Meeting, Intermountain Nurseryman's Association and estern Forest Nursery Council, Boise, Idaho, August 12, 13 & 14, 1980.

[2]Marvin N. Shearer is Extension Irrigation Specialist and Professor of Agricul-ural Engineering, Oregon State University, Corvallis, Oregon.

Application Efficiency = Average depth of water infiltrated and stored ÷ Average depth of water applied.

In Figure 1 we observe an irrigation requirement of one inch of water (the amount required to bring the soil to field capacity in this case). We turn the system off before any area receives more than one inch of water so that all water infiltrating the soil is stored. From five to ten percent of the water leaving the sprinkler may be lost by evaporation. Since there are no runoff or percolation losses, the application efficiency may be 90 to 95% with 100% of the water reaching the soil being stored there. Some areas, however, will be greatly underirrigated.

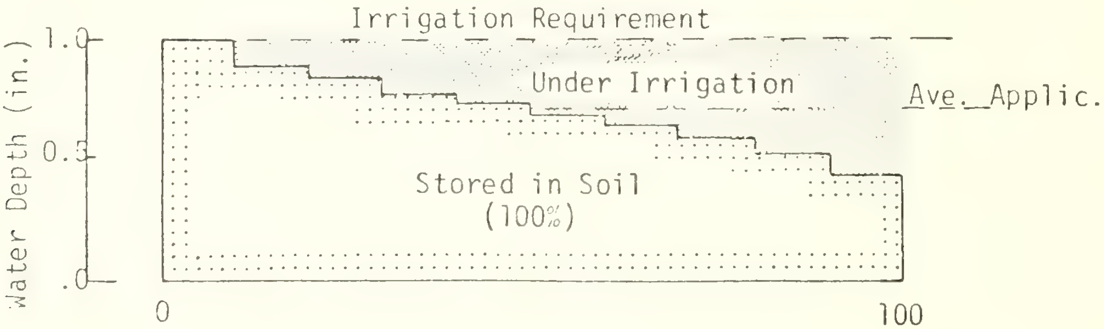

Figure 1.--Example of water distribution at 80% uniformity coefficient with severe under-irrigation.

The effect of extensive under-irrigation can be reduced by increasing the average amount applied and over-irrigating, as shown in Figure 2.

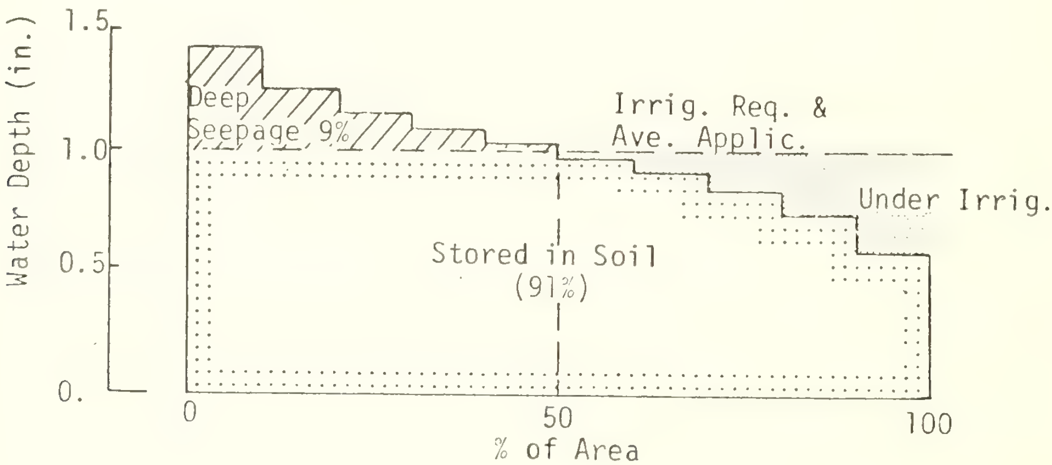

Figure 2.--Water distribution at 80% uniformity coefficient and 50% adequacy of irrigation.

Here we have the same uneveness in water distribution, but we have reduced the amount of under-irrigation 50% in some areas by over-irrigating an equal amount in other areas. Under conditions of good internal soil drainage this may not be too bad, but chances are for young tender plants, 20% of the area in this situation could have damaged plants due to lack of adequate water.

Under-irrigation can be reduced even more by increasing the average amount ap-
plied, as shown in Figure 3. Notice what has happened to the seepage loss. It has increased from 9% to 21% of the water reaching and infiltrating the soil. We would say in this example that we had achieved an adequacy of irrigation of 75%, which means that 75% of the area irrigated received the irrigation requirement or more, and 25% received the irrigation requirement or less.

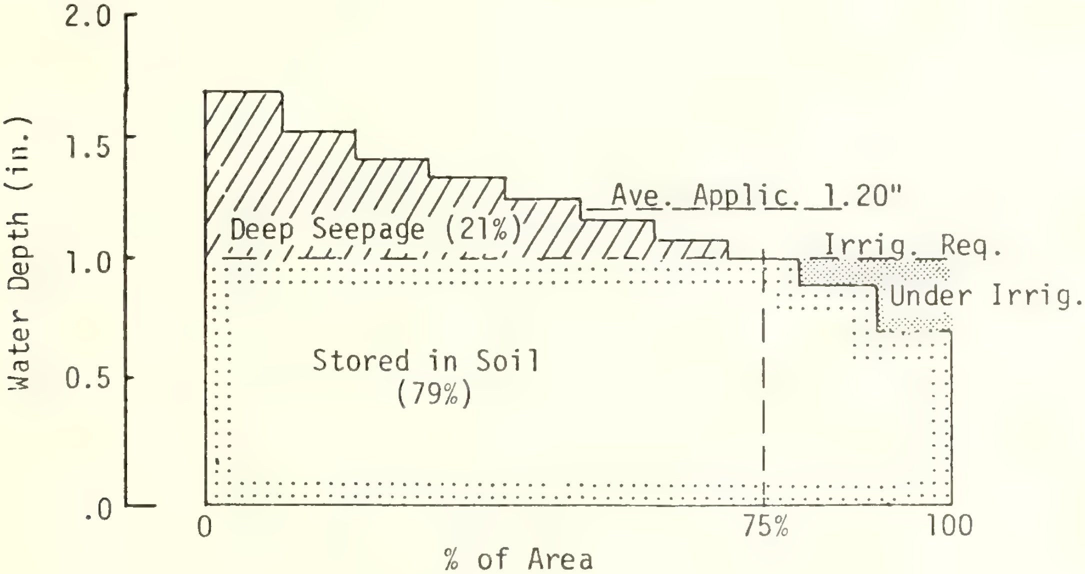

Figure 3.--Water distribution at 80% uniformity coefficient and 75% adequacy of irrigation.

Uniformity Coefficient

How uniformly water is applied to soil is described by a statistically derived number called a uniformity coefficient. In Figure 4 you see distributions for three uniformity coefficient values. Departure of depths of water applied from average application gives an indication of the extent of over- or under-irrigation. The question that must be answered by the nurseryman is: How much is he willing to pay for uniform distribution?

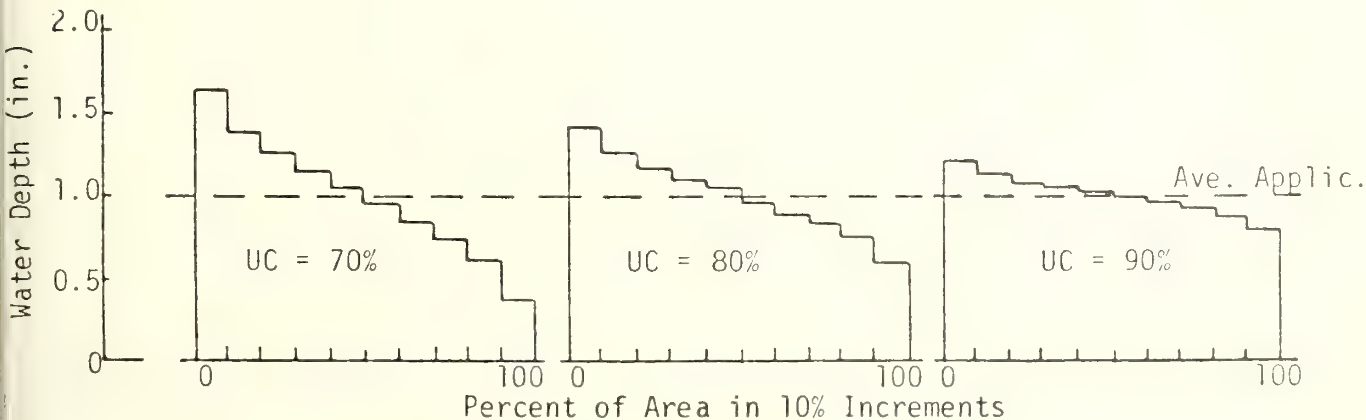

Figure 4.--Water distribution for three uniformity coefficient values.

I suggest that for high value crops having small root systems, such as nursery stock, the minimum acceptable value should be 85%. For high value crops with extensive root systems, such as full-grown trees, possibly 70% uniformity coefficient is acceptable. Plants with smaller root systems require higher uniformity coefficients since the root systems are unable to extend from areas of low water applications to areas of abundant applications. The extent of over- or under-irrigation is controlled by the adequacy of irrigation as described earlier.

ACHIEVING UNIFORM WATER APPLICATION

Uniform water application is achieved by selecting the correct combination of nozzle size, sprinkler pressure, and sprinkler spacing for the wind conditions which exist during irrigation. A number of sprinkler manufacturers have the capability of testing sprinklers to determine the performance characteristics of their sprinklers. But, very little of this information is distributed for public consumption. I am sure that if in our purchases, we specified uniformity levels that must be achieved after system installation, we would see a marked improvement in the performance of solid set sprinkler systems being installed in the field today.

Sprinkler systems that distribute water evenly cost more money than systems that don't, because they require more sprinklers, more pipe and more fittings. A purchaser must be willing to pay for a quality performing system. No supplier can bid a quality performing system without a corresponding increase in price.

Solid set sprinkler systems as they are generally sold, usually do not apply water as uniformly as side move or hand move systems. In an effort to reduce costs, sprinklers are spaced too far apart. They may be able to apply water in a somewhat satisfactory manner in winds of 0-5 mph, but when winds increase beyond this point water distribution falls off very rapidly.

Studies to determine the relationships between sprinkler application profiles, sprinkler spacing and eveness of water distribution were conducted as early as the 1930's. More recently studies of techniques used to predict uniformity of distribution under various wind conditions from sprinkler profiles obtained under no-wind conditions have been made. Unfortunately, this information is not readily available for all sprinklers or from all sprinkler manufacturers.

SPRINKLER SPACING RECOMMENDATIONS

A number of theoretical sprinkler profiles were studied by Christensen in 1942, and from these studies general conclusions were drawn which are still valid today. They don't take the place of specific data for specific sprinklers, but they are quite helpful when such information is not available - which is most of the time.

In general, his studies showed that when sprinklers are operated in winds of 0-5 mph and are spaced in a rectangular pattern, the maximum spacing in one direction should be 60% of the no-wind diameter and the sum of the two spacings 105% of the diameter.

In winds from 5 to 10 mph, maximum spacing should be 50-55% of the diameter and the sum of the two spacings 85% of the diameter.

There is usually no real advantage in using triangular spacings unless extended spacings are used. Extended spacings are 65% or more of the no-wind diameters. Such spacings prove disastrous though if even slight winds develop. The results of these extended spacings are apparent in many nurseries.

Continuously moving laterals provide the best uniformity because sprinklers are nfinitely close in the direction of the lateral move and can be spaced quite closely long the lateral. Unfortunately, these are not particularly adapted to nursery conitions because they lack the flexibility required under nursery irrigation programs. n addition, they cannot be used successfully for frost protection.

During the last few years there have been straightening veins added to impact prinklers for the purpose or straightening the flow through the sprinkler and inreasing the area covered by the sprinkler pattern. Unfortunately, another characeristic accompanied the increased diameter; a change in the sprinkler profile resultng in a deficit of water about one-third the way out from the sprinkler. In order o compensate for this, it has been necessary to increase pressure at the sprinkler y 5 to 15 pounds per square inch or to add a secondary small nozzle to fill in the rea not covered by the range nozzle. There is nothing wrong with small nozzles exept they plug easily when surface water is used.

RATE OF APPLICATION

A second factor affecting irrigation quality I wish to discuss briefly is rate f application.

In Oregon, Oregon State University has been involved in a cooperative program ith the Soil Conservation Service to test intake rates of soil under sprinkler irigation. We have used a portable water tank and a special designed sprinkler arangement which allows us to apply a wide variety of rates over a small area. Through isual observation and catch measurements of replicated sites we have developed "best stimates" of soil intake rate for use in sprinkler system design. These values are vailable in Soil Conservation Service Irrigation Guides.

If on your nursery you notice water ponding on the surface, or running off plots, ou are applying water too fast. Lower application rates are achieved with smaller prinklers and appropriate closer spacing. It is not accomplished simply by extendng spacings of existing sprinklers as such action will result in lowered distribuion uniformity.

Proper scheduling of irrigations, both time and amount, is also essential for uality irrigation. However, time has not permitted me to discuss techniques of chieving appropriate scheduling today.

SUMMARY

Uniform distribution of water is essential for quality irrigation. It is chieved through appropriate selections of sprinklers, sprinkler pressure, and nozle diameters. Such selection will provide appropriate application rates.

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FIELD HANDLING 1/

Glenn Jacobsen 2/

ABSTRACT

A field handling system for care of seedlings from the nursery to the planting hole has been implemented in the Intermountain Region of the Forest Service. This system has improved both survival and growth of the seedlings.

INTRODUCTION

Dick Thatcher asked Al Dahlgreen and me to explain how we handle seedlings from ie nursery cooler to the planting site and our planting procedure. I will cover the ield handling procedure and quality control in the Intermountain Region of the U. S. orest Service and the Payette National Forest. Al will then cover planting the seed- ings, inspection for quality, and results of our reforestation efforts.

Tree seedlings that are properly cared for during lifting, packing, storage, and ield handling demonstrate a great desire to survive and grow when outplanted. eedlings are living organisms subject to environmental factors. They can cope with iese factors in a suitable environment, but are extremely vulnerable to physiologi- il as well as mechanical injury when out of the ground. Seedlings are exposed to iny causes of injury from the time of lifting until outplanted. Survival and growth esponses are influenced by the number, degree, and duration of such injuries, in ldition to the site and other factors. These damaging effects are cumulative and are ften interacting.

A field handling system for care of seedlings from the nursery to the planting ole has been implemented in the Intermountain Region of the Forest Service. Refor- station personnel on the Payette National Forest have been following this system ince the early 1970's.

Our main objective in artificial reforestation is good survival and growth of eedlings to obtain a satisfactorily stocked, rapidly growing stand. To achieve this ojective, proper handling of stock from the nursery to the planting site is neces- iry. Our goals for handling stock are:

1. Minimize disturbance of seedlings.

2. Minimize variation from optimum temperature and relative humidity levels.

3. Minimize moisture stress, exposure, and mechanical injury.

1/ Paper presented at joint meeting of Western Forestry Nursery Council and itermountain Nurseryman's Association, Boise, Idaho, August 14, 1980.
2/ Forest Silviculturist, Payette National Forest, McCall, Idaho.

4. Provide for gradual transition of seedlings from storage to field conditions.

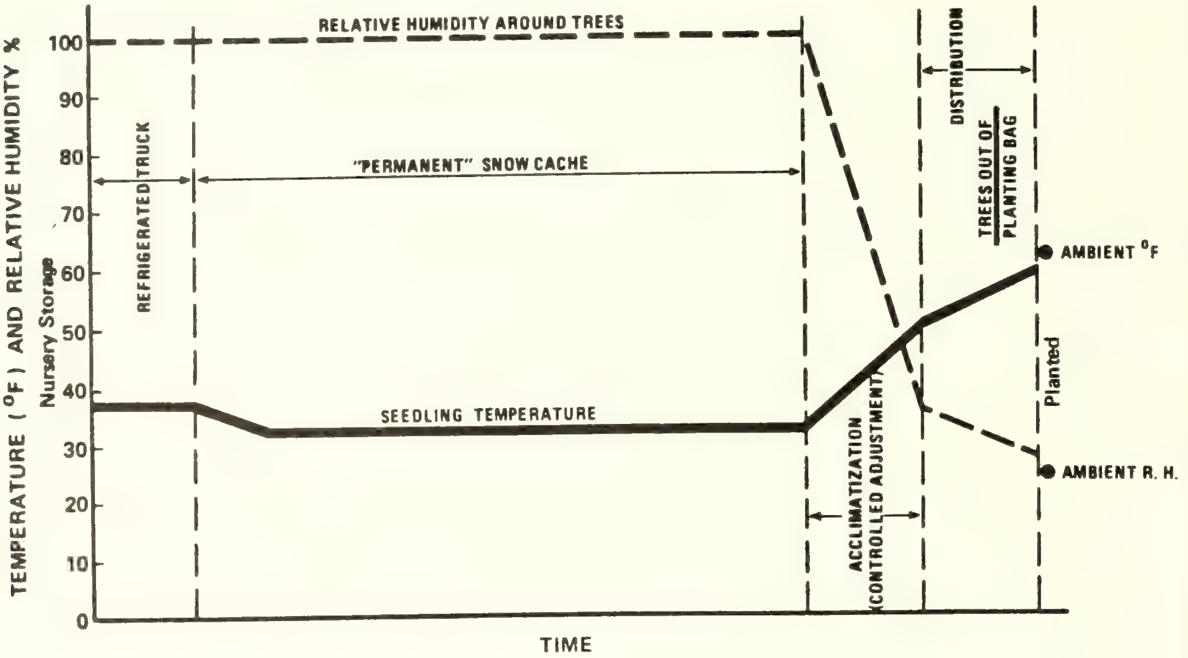

Diagram of temperature - relative humidity regimen considered ideal for seedlings during the nursery to planting hole journey in the Intermountain Region. The objective is to reduce the frequency and rate of environmental change which could injur the seedlings. (Time frame not to scale).

We obtain nursery stock from both Lucky Peak and Coeur d'Alene nurseries. Seedlings are generally lifted, sorted, and packed the end of February or the first part of March. During this time the District people are plowing snow to open roads to their snow cache locations for seedling storage.

LOADING

Bare root stock stored in nursery coolers is loaded on refrigerated trucks for delivery to the Forests. Racks are built in each truck to allow stacking of the crates without crushing, yet still leave adequate air space between crates to allow air circulation and prevent temperature increases. Seedlings are loaded by seed lot for each snow cache location. Trees are generally loaded the evening before delivery with the refrigeration units left in operation. The objective is to maintain a root mass temperature of no higher than 36° - 38° F. This is about the temperature we can currently expect seedlings to come out of the nursery coolers.

DELIVERY

Delivery occurs during the second or third week of March on the Payette National Forest. When possible, delivery is coordinated between Lucky Peak and Coeur d'Alene nurseries for the same day. Lucky Peak trucks generally arrive at the delivery points

at 0800. The trucks are driven directly to three of the four snow cache locations on the Forest. Due to a muddy, steep road on the Weiser Ranger District, seedlings are unloaded into a stake rack truck in a shaded location, covered with a tarp, and delivered to the snow cache. Thermometers are placed inside the refrigerated trucks to record root mass temperature upon delivery. The temperature readings are recorded on the delivery ticket for a permanent record. We document these conditions for evaluations of our plantations.

STORAGE

A day or two prior to tree delivery, each District prepares a packed snow floor for their snow cache. Minimum depth of the snow floor is two feet. This is necessary to prevent seedlings touching the ground if the snow melts.

We are faced with a storage period of two weeks to four months depending on elevations and aspects of planting sites. Sites are located at elevations of 4,000 to 6,500 feet above sea level. Planting begins at the lower elevations about the third week in April and may last until the third week of July at the high elevation spruce sites. The bulk of our planting is done in May.

Due to the length of storage, up to 120 days, we use a snow cache. Snow caches provide an environment of uniform high humidities and a constant temperature of 33^{o} F. This appears to be ideal for seedling storage. As with any job, there are proper procedures to be followed to prepare a snow cache.

When a refrigerated truck delivers seedlings to a snow cache, extreme care is taken when unloading seedlings to prevent damage to the buds, especially ponderosa and lodgepole pine. Seedlings are packed in lettuce crates specifically for snow cache storage as trees are least susceptible to damage in a crate. Boxes or bags may be crushed when snow is piled on them.

Crates are stacked in an orderly manner with boards between the third and fourth crates. This helps in removal of crates. Root mass temperatures and ambient humidities have been monitored inside the cache. A properly constructed snow cache will maintain a temperature of 33^{O} F. and a relative humidity of 100%. Stacks of crates have air spaces between them and rows are spaced one to two feet apart. Snow is shoveled between the stacks and the rows until there is enough snow covering the crates to utilize a tractor to pile four feet or more of snow over the trees. A sawdust layer of up to one foot deep is then placed over the snow for insulation, plus a canvas on top of the sawdust. Canvas helps reduce snow melt. A map showing seed lot location is prepared to assist with proper removal of the trees. It is generally less than two hours from the time of unloading the trees until they are covered by snow.

The cache is generally not opened until two days before tree planting begins. Extreme care is taken to remove only the minimum amount of snow needed to create an opening to the row of trees which will be planted first. The opening is then closed with insulating material when not is use in order to retard snow melt and maintain existing temperature and humidity inside the cache.

ACCLIMATIZATION

Trees are prepared for acclimatization and field distribution by dipping their roots in a vermiculite and water slurry and rolling them in wet burlap. Water held by the vermiculite is readily available to replace any the trees may have lost in storage,

as well as that which will be transpired prior to planting. The wet vermiculite particles help reduce root stripping by acting as a lubricant; they maintain a film of moisture on the roots during the brief journey from planting bag to planting hole, and they aid planting inspections by "marking" seedling roots.

The burlap protects the tree roots from mechanical injury or exposure, assures good root contact with moist material, and binds the seedlings in a safe and convenient package for field transportation and distribution. The entire procedure has a beneficial psychological value, reminding all concerned of the need for extreme care in handling trees.

A shaded tent is used for packaging trees. It is large enough to accommodate a two-day supply of trees, a work table, two large garbage cans, and one or two tree handlers. It may be located near the snow cache, or at the planting area. Trees are transported from the cache to the dipping and wrapping area in an insulated pickup box or a tree trailer on an "as needed" basis. Trees are removed from snow cache in early morning or late evening and moved to the acclimatization facility in a tree trailer. A one- or two-day supply is removed at each entry if the usual 24-hour acclimatization period is used. Number 4 horticultural vermiculite is mixed into a large garbage can of water to make a thick slurry and allowed to soak until well saturated. A second garbage can is used to soak 20-inch by 30-inch pieces of burlap which have been impregnated with mud to improve water retention.

A piece of the wet burlap is spread on the table and a handful of seedlings is removed from the shipping container. Roots of trees remaining in the container are kept covered. The trees are grasped with both hands so their roots tend to spread. The roots are then dipped into the slurry and gently agitated until thoroughly coated with wet vermiculite when removed. The slurry is kept stirred, since wet vermiculite sinks. The seedlings are gently separated and arranged in an orderly manner on the burlap with roots parallel to the short axis, and root collars about one inch below the upper edge of the burlap. Additional seedlings are similarly treated until the desired number (usually 50 to 100, depending on tree size and weather conditions) are in place. Roots may be trimmed so they are within specifications--(12 inches).

The exposed flap of burlap is folded over the roots, care being taken not to bind any roots in the fold. The burlap, with trees in it, is firmly rolled from one end to the other, jellyroll fashion. The outer end of the burlap is pinned or tied in place. The resulting package must be firm so trees have good root contact with the wet material and will not fall out. Proper placement of trees on the burlap and correct rolling facilitates removal of the trees with minimum root stripping.

Acclimatization is completed in the packaging tent, or in a snow-free tree trailer. Trees can be more gradually brought into equilibrium with an environment near that which prevails on the planting site, if temperatures and humidities surrounding the trees are monitored occasionally at different points in the handling process. Procedures can then be changed to soften any stressful conditions noted.

The packages of trees are stacked in single rows on low platforms of lumber or poles. The burlap-covered roots are aligned vertically and horizontally within the stack, with tops alternating from side to side to permit free air circulation around them. Stacks are no more than five or six packages high, and tops of trees in adjacent rows are at least one foot apart.

Newly packaged seedlings should be covered with light canvas or other material which is removed as the trees approach equilibrium with the surrounding environment. Doors of tree trailers are adjusted to achieve similar control.

Trees should be protected from freezing by covering with insulating blankets or holding them at the desired temperature in insulated trailers. Protective coverings are removed, or tree trailer doors reopened, when freezing conditions no longer prevail.

Longer acclimatization periods (up to 48 hours) are required during warm, dry weather than on cool, humid days. Seedling temperatures should be near the soil temperature at a depth of 8-10 inches, or air temperature, whichever is lower, at the time of planting. Humidities around their tops should approximate that found in the shade near the ground on the planting site.

DISTRIBUTION

Trees are brought from equilibrium with the environment at the acclimatization site to equilibrium with that of the planting site during the distribution process. They should suffer little stress if differences in temperature and humidity between the two sites are not great and the transition is not rapid.

Trees are issued for planting in the same order they were packaged. They are not placed in or on snow or ice, nor are their tops covered by wet burlap or other material (except as protection from freezing) after acclimatization has started. Such "protection" nullifies the benefits of acclimatization.

Trees are kept in the shade and protected from the wind while being transported or held at the planting site. A pickup truck with a cover may be closed while moving and opened when stopped to provide ventilation when parked. Wet burlap placed over the root zone (not on the foliage) of stacked trees will slow drying of the top layer of tree packages.

Trees are placed in clean planting bags. The nail or string holding the tree packages together is removed after the trees are in the bag or tray, but before trees are removed. We use planting bags 18 inches deep, generally of white canvas with a shield of waterproof material on one side to protect the planter from water seepage.

In addition, inspections and documentation of care of the planting stock are done on a daily basis.

EVALUATION

Thermometers are standard equipment for reforestation personnel. They are used frequently during the storage and handling of seedlings to monitor temperatures. We also request assistance from Russ Ryker, silviculture researcher from Intermountain Forest and Range Experiment Station, to use an oscilloscope or other techniques to monitor seedling condition if something looks strange to us.

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FIELD HANDLING AND PLANTING

PLANTING

Allen K. Dahlgreen [1/]

ABSTRACT

A program was initiated in the USDA Forest Service Intermountain Region in 1968 which significantly improved performance of forest tree plantations on National Forest lands within the Region. A substantial part of this improvement can be attributed to the application of quality control procedures to the field planting operations.

INTRODUCTION

I am sure you wonder why discussions of field handling and planting of forest tree seedlings have been included in your agenda.

Our purpose is to extend and increase your concern for quality reforestation beyond the nursery gate and through the field storage, handling, and planting process. To do this we will point out the need for a high level of quality control in outplanting operations, and describe some handling, planting, and quality control techniques which have proven effective in the Intermountain Region of the U.S. Forest Service. We hope to thereby encourage you to become involved in the reforestation efforts of those who use your seedlings - visiting ongoing and past projects, making observations, asking questions, offering suggestions, and monitoring performance. The goal is better survival and growth, and greater satisfaction for all concerned.

Those who purchase or use the seedlings you produce expect and deserve good survival and growth from those trees. Poor plantation performance, regardless of cause, reflects adversely on your facility and degrades the image of artifical reforestation in general. It is costly in terms of monetary and resource values.

However, the very best trees, grown, packaged, and stored under strict controls, will not perform properly if planted "offsite" or subjected to improper field handling and planting procedures. The need for quality control does not cease when the trees leave the nursery--it becomes more acute.

Seedlings in the nursery are under intensive care. They are tended, for the most part, by a small group of skilled technicians and professionals whose primary concern, yearlong, is the well-being of the trees.

On the other hand, the skill levels and concerns of those who handle and plant the trees in the field vary greatly. Some are aware of and apply excellent field

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storage, handling, and planting procedures. Others want to do the job right--but don't know how--and fail to ask someone who does. And some consider tree planting a futile, unpleasant task to be disposed of as quickly as possible. In any event, problems develop on even the best organized projects. People develop bad habits as work progresses; they become tired, erroneous beliefs surface and are applied, important details are overlooked in the rush to get the job done, and equipment malfunctions occur. Murphy's Law never fails!

These are but a few of the general situations I have repeatedly encountered in 20 years of intensive involvement with forest tree planting. I mention them to emphasize the need for effective quality control after the trees leave the nursery. Some of you have had similar experiences.

THE INTERMOUNTAIN REGION, U.S. FOREST SERVICE EXPERIENCE

The U.S. Forest Service Intermountain Region experienced good survival and growth of planted ponderosa pine (*Pinus ponderosa* Laws.) seedlings through the late 1950's and early 1960's. Most of this was early season (low elevation) machine planting on machine terraced, stripped, or furrowed sites. Plantation performance declined as work progressed to more difficult terrain and higher elevations. It became necessary to depend on hand tools for site preparation and planting; seedling storage periods increased from weeks to months; seed source, species, and site coordination became more difficult.[1/] Hot, dry weather during planting became common as planting seasons extended into the summer. The limited data available indicates that Regional average first-year survival had slumped to 65 percent or less in the 1966-1969 period.

A program to improve plantation performance was started in 1968. This included betterment of conditions and operations at Lucky Peak Nursery as well as improvement of field storage, tree handling, and planting procedures.

The following is a tabulation of the Regional average first-year plantation survival as summarized from reports of each National Forest in the Region for each year since 1971 (U.S. Forest Service, 1979):

Year	Percent Survival
1971	70
1972	75
1973	88
1974	88
1975	86
1976	83
1977	89
1978	80
1979	73

These data represent, with few exceptions, survival determined from individually staked trees on about 90% of the acreage planted each year. The depressed survival in 1979 may be attributed, at least in part, to weather conditions. Data from many weather stations show that 1979 was the driest year on record for 40 years or more (U.S. Forest Service, 1979) over much of the Region. Fire weather conditions were the worst in the history of the Region (U.S. Forest Service, 1980).

1/ Species commonly planted include ponderosa pine (*Pinus ponderosa* Laws.), lodgepole pine (*Pinus contorta* Dougl.), Rocky Mtn. Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn) Franco.), Engelmann spruce (*Picea engelmannii* Parry.), blue spruce (*Picea pungens* Englem.), and western larch (*Larix occidentalis* Nutt.).

The "Wyoming Utilization Study" (Lotan and Perry, 1977), (Schmidt and Lotan, 1980), was initiated in 1971 on the Bridger-Teton National Forest in western Wyoming. The study area was at an elevation of about 9,300 feet (2,850 m) above sea level. Trees planted in 1973 in the reforestation phase of the study demonstrate the results obtainable when trees from the proper seed source are properly stored, handled, planted, and protected:

> Only seven of the 1,560 staked 2-0 lodgepole pine sample trees died the first season after planting. Initial survival for all harvest/fuel treatment methods was thus over 99.55 percent.
>
> Fifth-year survival on the broadcast burned and tractor piled and burned fuel treatments was over 87 percent. Average height of these trees was over 45 centimeters; some trees were over 90 centimeters tall.

The performance achieved cannot be attributed solely to the tree handling and planting procedures used. Work by Research Foresters Russell A. Ryker and Raymond J. Boyd of the USDA Forest Service Intermountain Forest and Range Experiment Station, former Lucky Peak Nurseryman Frank E. Morby, and more recently your host, Richard H. Thatcher, were essential to these successes.

Glenn Jacobsen has already discussed the field storage and handling procedures which we found essential to success. I will now try to explain what we consider good planting quality and how we obtained it in the Intermountain Region. Many of these ideas and procedures have been around for decades, people just weren't using them. Others developed as work progressed. The program benefitted from the inputs of many technicians and foresters, and several USDA Forest Service Contracting Officers! We hope you and others may find this information useful.

THE BASIS FOR QUALITY TREE PLANTING

Quality control involves more than conducting inspections to determine whether certain tasks have been done to specifications. It must be designed into the project in the form of tools and procedures that simplify the work, are relatively easy for the workers to use, and which minimize the probability that things will be done incorrectly. Training must be appropriate and adequate at all levels. Skilled supervision/contract administration must be provided. Finally, inspectors must be thorough, fair, and work closely behind planting crews. Subsequent followup on plantation performance provides data on overall program success, and often helps identify procedures that need improvement.

The biological and physical needs of the trees, insofar as we were aware of them, dictated the planting standards which evolved. The eleven inspection elements commonly recognized, and a synopsis of standards applicable to each, are as follows (for the full standard, please see the USDA Forest Service "Westwide" Tree Planting Contract developed in 1978.):

1. Tree spacing - prescribed to fit site requirements; limited variation permitted.

2. Planting spot selection - where local features provide best protection from hazards.

3. Site preparation - at least 24" x 24" to mineral soil, configuration as specified.

4. Tree location on spot - near center of site-prepared spot if applicable, no less than 9" from live vegetation.

5. Planting depth - soil shall be even with original ground line of trees; no roots exposed; no branches or needles covered.

6. Stem position - at an angle between perpendicular to the slope and true vertical.

7. Planting hole orientation - same as stem position.

8. Root configuration and orientation - roots aligned along the axis of the planting hole, extending downward in a near natural arrangement; not doubled, spiraled, bunched, or bent.

9. Root damage - roots shall not be shortened, pulled, stripped, crushed, or abraded.

10. "Foreign" material in the hole - moist mineral soil only around the tree roots Dry soil, ash, organic matter, rock, and other material shall be kept out of the holes.

11. Soil firmness around roots - soil shall be filled in and firmed progressively so no loose soil or air pockets remain, and tree is as firmly planted as soil conditions allow.

Certain procedural requirements must also be adhered to. Some of these are listed here:

1. Snow or ice must be kept off of trees that have been acclimatized.

2. Trees must be kept in a shaded location, out of the wind when not being carried by a person actively engaged in planting. This applies during rest and lunch breaks as well as in stockpiles.

3. Trees must not be exposed to the fumes of petroleum products or other harmful substances.

4. Trees shall be gently removed, one at a time, from the planting bag or tray, and quickly and gently inserted in the planting hole.

5. "Slit" planting will not be permitted. Planting holes must be "broken out on three sides" or drilled with a 4" diameter auger capable of making a hole 14" deep. (Tree roots are 12" long.)

6. Planting holes must be filled and firmed by hand only. Sticks, trowels, and other tools must not be used to fill or firm the soil. The soil may not be firmed with the boot heel.

PLANTING METHODS

Planting machines best meet the criteria mentioned earlier for promoting quality planting. They are simple and easy to operate once they have been attached to the tractor and essential adjustments properly made. Few people are involved, and operators need not learn difficult or complex procedures, even on the nonautomatic machines, which

are best for stoney ground. Additional firming of soil around the tree roots may be necessary on heavy soils. However, this is seldom a problem, and an extremely high percentage of properly planted trees can be obtained on machine planting projects.

A variety of planting hoes, planting bars, dibbles, modified tile spades, and shovels have been used for tree planting. These tools require considerable skill and physical strength of the user. In addition, many people must be trained to properly select (and often site prepare) planting spots, drive the tools into the ground, open the planting hole, insert the tree (often into a tangle of roots), make sure the tree roots are straight, and close the hole so the soil is in firm contact with the tree roots. Proper planting by these methods is quite complex and is physically difficult for many people. There are a great many opportunities for error since each planter is repeatedly faced with a variety of problems and obstacles to good planting. Very close supervision/contract administration and inspection procedures must be exercised to maintain planting quality in most situations where these tools are used.

Powered soil augers meet the criteria for promoting quality planting. Although this method is not nearly as automated as machine planting, it is applicable to a much wider range of soil and terrain conditions. Auger planting has an advantage over machine planting in that it does not create artifical burrows which may promote gopher damage. The use of soil augers breaks the planting operation into two components: hole making and planting.

The auger operators select the planting spot (unless already selected by the "scalping" crew) and drill the planting hole to the proper depth at the correct angle. The auger excavates the soil and small rocks, cuts small roots, and pushes larger rocks aside, depending on soil conditions. The result is a clean four-inch diameter hole to the proper depth. The excavated soil is neatly deposited around the hole. Well coordinated people with reasonable strength are easily trained to be good auger operators.

The planters have a fairly uniform situation at every planting spot: a clean planting hole to specifications with a supply of replacement soil close at hand. They need only pull aside the small amount of loose soil in the bottom of the hole, insert the tree to the proper depth (straightening its roots as they do so), and progressively replace and firm the soil around the roots. Modest strength and reasonable dexterity is required for this work.

Auger planting quality is greatly enhanced when preceded by suitable machine or hand site preparation. This treatment should, in addition to reducing competing vegetation, remove ash, organic matter, and dry soil that might get into the planting hole; provide a smooth surface on which the excavated soil may be deposited; and provide a convenient work surface for the planter.

High quality durable equipment is available for planting trees with powered soil augers. The "Cannon DH-2W" auger transmission quickly turns a chainsaw into a very good auger power unit. The 4" "Carbide-1000" and "Thomas Loc-Tip" augers are durable and efficient digging tools which will fit several different auger transmissions. These tools have greatly expanded the range of soil conditions in which auger planting can be used.

There is no magic involved in auger planting. It is subject to poor workmanship as is any other method. However, it is easier for people to plant properly with soil augers, on suitable sites, than with hand tools, if given good equipment, training, and supervision.

The use of soil augers is strongly encouraged throughout the Intermountain Region. Extended (to 16") KCB, or similar planting bars are recommended on sites that are too

stoney for augers. A planting hole broken out on three sides and hand replacement of soil is then required. Planting machines may be used when site conditions, project size, and machine availability make it practicable.

I recently prepared a pamphlet "Planting Tree Seedlings with Powered Soil Augers." It explains in detail some of the requirements and procedures for successful auger planting. It will soon be available from International Reforestation Suppliers, Inc., P. O. Box 5547, Eugene, Oregon 97405. This firm also handles the "Cannon" transmissions and "Carbide" augers. The "Thomas" augers are available from Southern Oregon Reforestation, Inc., 6517 Pioneer Road, Medford, Oregon 97501.

PLANTING QUALITY INSPECTIONS

Planting quality inspections are required on all plantations. Inspections are conducted concurrently with planting operations. The project foreman or the contractor is promptly advised of any inadequate planting quality, or any unsatisfactory procedures that are detected. A two-phase system of inspection has proven most effective.

The first inspection phase is aimed at preventing errors before they occur--or at least confining them to only a few trees. One or more inspectors circulate throughout the planting operation. They watch to see that site preparation, hole opening, and tree handling and planting procedures are correct. They are especially alert to see that trees are properly protected and handled before and during planting, and that forbidden procedures are not used. Errors observed are immediately reported to the foreman or contractor and documented if appropriate.

The second inspection phase is the basis for evaluating project crew performance and for possible adjustment of the per unit bid price for planting contracts. These inspections consist of detailed examinations of the planted trees on a series of 1/50- or 1/100-acre sample plots, aggregating one percent or more of the area planted. All trees on each plot are checked for compliance with elements 1 through 6 as listed in the section "Basis for Quality Planting." The number of trees on the plot which meet this test is the basis for determining the number of trees which are excavated to determine compliance with elements 7 through 11. Trees not in compliance with all 11 elements, as appropriate, are declared "unsatisfactory." Results are documented on a special form for subsequent summary and analysis.

Little variation from prescribed tree care and planting standards is tolerated. For example, trees are considered "wasted" and are discarded if they have been contaminated by petroleum products or fumes. The same applies to those whose roots are exposed to sun and wind by planters carrying them in their hand from one planting hole to another. Experience has shown such trees will die or do poorly. A charge is made for "wasted" trees on tree planting contracts.

Compliance with inspection elements 1 through 6 is easily determined by examination and measurement of surface conditions. Elements 7 through 11 can only be adequately inspected by digging a hole (a round pointed tile spade is preferred) immediately adjacent to the planting hole and gently removing the soil around the tree roots without disturbing the tree. A bulb trowel and an ice pick or awl are excellent tools for this work. Voids (air pockets) are easily detected, and general soil firmness ("as firmly planted as soil conditions allow") is indicated by soil resistance to tools and fingers.

The only deviations from a "near normal" root configuration that is acceptable are those which developed in the nursery. This may be tested by removing the newly planted tree from the planting hole. If the abnormality persists without being held in place by soil, it is accepted.

All roots must extend downward (except as described above), and no degree of "J" or "L" configuration is acceptable.

Trees that are found to be properly planted may be left in place, and moist mineral soil replaced and firmed around the roots. Others should be removed and planted properly.

Inspectors must be well trained and impartial. Each one should plant and then inspect a few trees every few days to maintain a feel for soil conditions. Doubtful situations (is it good or bad?) may be settled on an alternating basis. Foremen and contractors are invited to observe inspections.

The often-used firmness test of tugging on a few needles is inadequate. The top of the planting hole may be easily crimped to hold the tree very tightly, masking loose soil and voids around the roots. Similarly, lifting the tree out in a "plug" of soil, which is then removed to expose the roots, masks errors in planting hole orientation, root configuration, and soil firmness around the roots.

TRAINING

Region-wide tree planting training sessions are held to improve planting quality and, hopefully, plantation performance. The program that evolved has several objectives, including:

Develop a success-oriented attitude about tree planting throughout the Region.

Make all concerned personnel aware of the Seed Zone Program and the need to get the proper species and seed source on each planting site.

Replace incorrect tree handling and planting practices with proven correct standard procedures.

Encourage use of soil auger planting on suitable sites.

Gain acceptance and conformity to the Region-wide standard tree planting contract (now the so-called "Westwide" tree planting contract).

Improve and gain uniformity in planting contract preparation, administration, and inspection.

Increase cooperation between nursery people, contracting personnel, and field technicians and Foresters.

Create opportunities for exchange of ideas and experience across administrative boundaries.

Teach people how to teach successful tree handling and planting techniques.

Attendance at one of these training sessions every 3 years (two or more are held annually at convenient times and locations) is required of all who are responsible for some phase of the planting program. This includes contracting officers and the Lucky Peak nurseryman and assistant as well as reforestation specialists, work supervisors, inspectors, contracting officers' representatives, and Silviculturists. Repeated attendance is required so that those involved can keep current with changes, contribute from their experience, and correct any bad habits they have developed.

Training is conducted by the most qualified reforestation and contracting specialists available. The one-day classroom session consists of a slide presentation depicting the consequences of inadequate consideration of seed source, planting techniques, and plantation protection. Emphasis is placed on the fact that well-grown, handled, planted, and protected seedlings will survive and grow very well. The program is followed by presentations on contracting and administration authorities, project and contract planning and preparation, project supervision, contract administration, inspection, and training.

The second day is devoted to field demonstrations of proper tree handling, site preparation, planting, and inspections. Trainees are required to practice all procedures demonstrated. They also must inspect a plot of trees that contains specific planting errors and report on their findings.

FOLLOWUP

Plantation performance must be monitored. Regional policy requires that at least 25 trees be staked on each plantation when established. More staked trees are required on larger areas. Survival of these sample trees is determined after September 15 of the first, third, and fifth seasons. Survival data, by species, is analyzed for each planting area, Ranger District, Forest, and for the Region as a whole. Costs per acre, per planted tree, and per live tree are derived. Summaries of the data, under a cover letter by the Regional Forester, are circulated to Forests, Ranger Districts, the Lucky Peak and Coeur d'Alene Nurseries, and other interested persons.

Use of "representative" staked rows may have some statistical shortcomings. However, they provide an index of seedling performance by seed lot, planting crew, weather conditions, and other variables which, if adequately documented, can help identify factors that depress seedling performance.

Plantations should be checked several times during the first growing season to identify problems and probable causes. Trees that turn brown a few days or weeks after planting were probably dead, or nearly so, when planted. This would indicate preplanting handling problems. Failure to acclimatize the trees properly may cause the needles and buds to droop or become flaccid a few hours after planting. Trees responding in this manner will probably develop short leaders and needles on the initial growth and suffer depressed growth for some time. Other stressful situations, such as broken dormancy, root damage, and fluctuating storage temperatures and humidities may cause similar symptoms.

Plantations must be visited often enough that damage by gophers and other rodents, livestock, big game animals, and other agents is detected before serious losses occur. Gophers and livestock are generally considered the most serious cause of plantation damage in the Intermountain Region. They are often the leading cause of seedling mortality. It is important that such damage be detected before it becomes widespread and while the causative agent may still be identifed so that appropriate and timely protective or corrective action can be taken.

Trees that are well grown and handled, properly planted on site, and protected, will make good growth from the start. Bud burst and top growth will be near normal, as will needle development. Root growth will be vigorous. Such trees will increase in height (from root collar) by 30 to 100 percent or more the first year, depending on initial height. Growth will accelerate annually until it reaches the site potential.

A means of evaluating plantation growth is badly needed. Efforts are underway in the Intermountain Region to develop meaningful ways of doing this.

One approach, which can be applied as soon as the new growth hardens off the first season is to classify leader/needle development of a sample of trees. Four classes are used: a) normal, b) near normal, c) abnormal, and d) aborted. Experience shows that few of the "a" and "b" trees will subsequently die; while more of the "c" trees and many of those classified as "d" will succumb.

Initial growth can also be used to evaluate performance the summer or fall after planting. However, such measurements must be correlated with seedling size. We have found that the smaller seedlings usually grow less in actual elongation, but more in percentage of initial height, than do the larger trees. Table 1 shows this relationship for 2-0 lodgepole pine planted in 1977 on the Twin Falls District of the Sawtooth National Forest. Seedling performance in terms of leader development class has been included.

Table 1.--Relationship between seedling height when planted (initial height) and leader elongation during the first growing season

Initial Height	No. Trees in Sample	1st Yr. Growth	Increase in Height	Trees in each leader development class			
				a	b	c	d
cm		cm	%				
3	21	2.8	94	11	1	7	2
4	49	3.5	87	36	2	9	2
5	70	4.0	80	55	3	9	3
6	81	4.3	72	67	2	5	7
7	80	4.9	71	72	2	5	1
8	70	4.9	61	65	1	1	3
9	43	5.0	56	36	2	3	2
10	30	5.8	58	26	1	1	2
11	21	5.2	48	19	-	-	2
12	19	6.6	55	18	-	-	1
13	4	6.3	48	4	-	-	-
14	5	4.8	34	4	-	-	1
15	2	4.5	30	1	-	-	1
16	1	7.0	44	1	-	-	-
Avg. 7.1	496	4.6	65	415	14	40*	27*

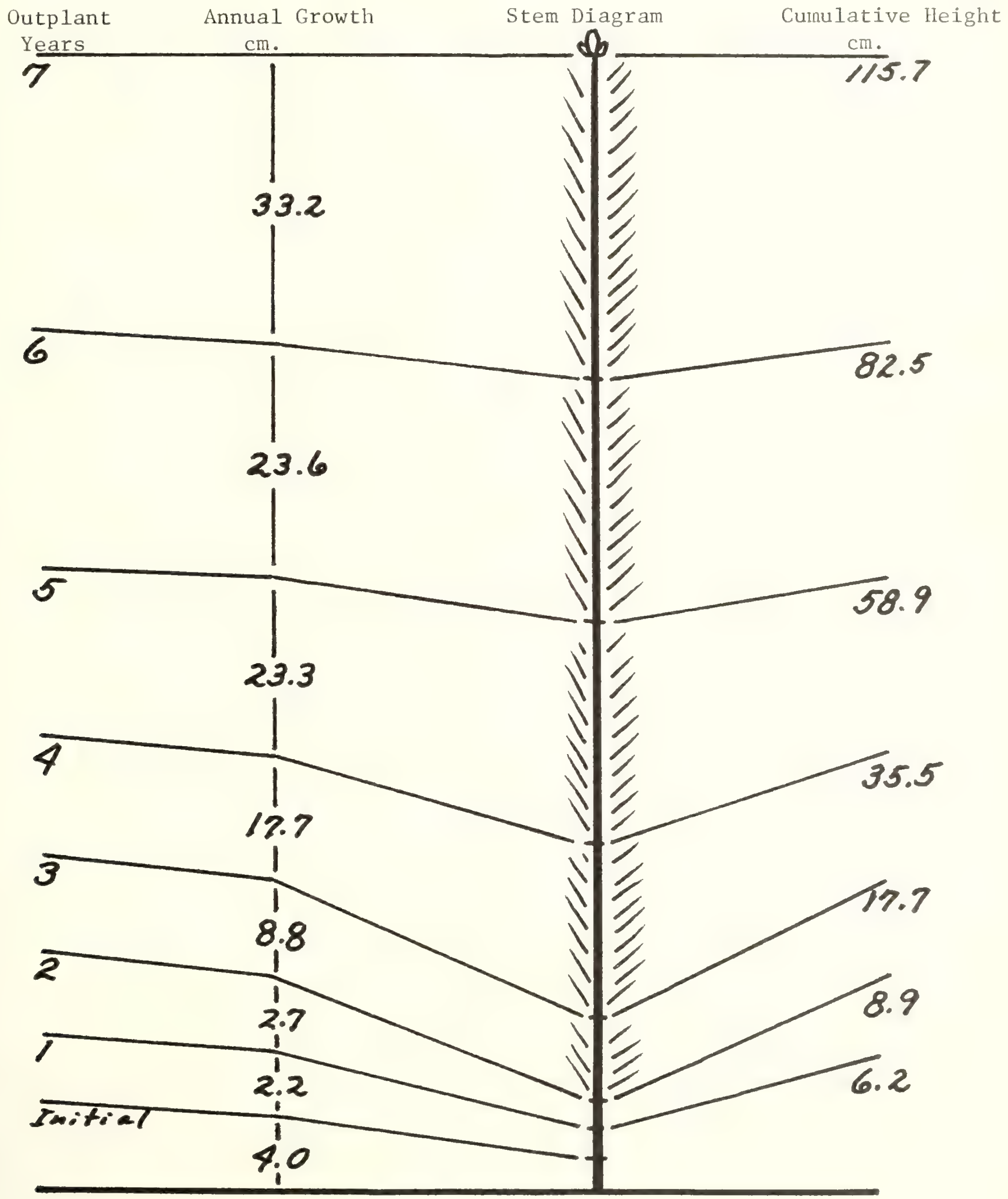
*About 14 percent of the trees fell in the "abnormal" and "aborted" leader classification. This resulted in substantial depression of average growth for the project and provides a clue as to the amount of mortality that can be expected in years 2 and 3

A third potential means of evaluating growth performance would be through collecting annual growth data on selected plantations for different species and sites. These data could be used to develop "plantation expectation charts" against which the growth of any plantation of the same species on similar sites could be compared at any point in time. This comparison capability would also make it possible to make some predictions as to future plantation performance. Figure 1 is an example of such a chart of the performance of 1-0 ponderosa pine seedlings planted in the Cold Springs area of the Idaho City Ranger District, Boise National Forest in 1974.

Figure 1

Plantation Expectation Chart (Height)

pecies - PP; Stock - 1-0; Seed Source - Idaho City; Planted - 1974; H.T. - Not Avail; ite Index - Not Avail; Planting Method - Auger; Planting Quality - Good (90+); No. of ample Trees - 35; Other - Annual Gopher Control; Location - Cold Springs Creek, daho City R.D., Boise N.F.



CONCLUSION

Our experience has shown that we can get excellent survival and growth from planted forest trees throughout the Intermountain Region. I am sure that similar success is attainable over a much wider area. However, it is essential that the basic principles, to which new techniques have been or may be adapted, be closely followed. We have been accused by some of being too "zero defect" oriented. Unfortunately, if you compromise planting quality, allowing a small percentage to die for the sake of economy, a disproportionately larger percentage gets sick, and doesn't perform.

Attention to detail is what counts, and the people who use your trees often don't know the details. Dialogue between nursery people, research people, and those who use the trees will benefit all. Invite those who use your trees to visit your nursery, examine the stock, and discuss details. Provide basic instruction and reference material on provenance, seedling care, planting procedures, and plantation protection to those who may not be aware of these needs. A visit to the "home ground" of some of your "customers" can pay big dividends. Sharing ideas, skills, and concerns helps build the good relationships required for successful plantations. Remember, the order for a few hundred or thousand trees from a small user may have little significance to your operation, but it is extremely important to that person.

Extend your vision and effort beyond the nursery gate--there is a big world out there and a lot of people who need your help.

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MINE AND ROADSIDE REVEGETATION IN MONTANA

Intermountain Nurseryman's Association
Western Forest Nursery Council
Boise, Idaho
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ABSTRACT

Presently in Montana and surrounding states, revegetation research and development activities are being concentrated on the rehabilitation of surface mined lands, while little research is being directed toward roadsides. Rapidly expanding mining activities and increased public concern for the environment have resulted in increasingly high standards for land rehabilitation. These developments are creating numerous challenges and business opportunities for nurserymen and related professions.

INTRODUCTION

I was requested to speak about roadside and mineland revegetation projects and ecent developments in Montana. Roadside revegetation research has received little ttention and project procedures have remained relatively unchanged during the past hree years. However, coal mining related activities in the Western states have ncreased at an exponential growth rate during the last several years. Consequently, will direct most of my comments toward the development trends and immediate needs mining related reclamation programs. Never before has land rehabilitation xpressed a greater need for the professional services of nurserymen, landscape rchitects, botanists, ecologists, and other land rehabilitation specialists. The ncreasing amounts of land disturbance combined with greater public concern for proper ind management practices has resulted in a new era of land rehabilitation. We as a rofessional group are directly involved and are responsible to meet the higher tandards of this new era by developing improved techniques and materials to successilly and economically rehabilitate disturbed lands. Modern land rehabilitation has volved to a precise scientific field which demands specific procedures and high aliber training.

Recent data indicate that the intermountain area is and will continue to be bjected to extensive mining activity. An Associated Press release summarized the tuation as follows. "The states of North Dakota, South Dakota, Colorado, Montana, oming and Utah will be producing 30 percent of the nations coal by 1985, up from percent only five years ago. The region's electric generating capacity will have ubled from 1975 to 1985, increasing from 3 to 5 percent of the nations total. Some percent of the country's uranium will come from the region by 1985, more than

doubling the current 10,000-ton-per-year output. By 1990, half the oil produced in the six states is expected to come from oil shale." The above statistics indicate that the need for land rehabilitation will substantially increase.

CURRENT AND FUTURE EXPECTATIONS

In recent years stringent Federal land rehabilitation requirements have been implemented which require the states experiencing surface coal mining activities to develop and implement equally restrictive requirements (U.S. Office of Surface Mining, 1977). Many western states have developed proposed regulations which are now being acted upon at the Federal level. In the near future I believe many of these restrictive requirements will influence reclamation standards of other projects such as roadsides, utility corridors and urban development. As an example of what may soon confront us, I will read to you selected requirements included in the recently proposed Montana Surface Mining Control and Reclamation Act (State of Montana, 1980).

Please keep in mind, that the primary reason Montana imposed these laws was to prevent the Office of Surface Mining (OSM) and Environmental Protection Agency (EPA) from controlling Montana resource development.

Montana regulations now require that a diverse, effective, and permanent vegetative cover of the same seasonal varieties native to the area of land to be affected be established.

Several of the guidelines used to determine if the above standard for revegetation has been met include the following:

1. Success of revegetation shall be measured on the basis of unmined reference areas approved by the department. The department shall approve the estimating techniques that will be used to determine the degree of success in the revegetated area. At least one reference area shall be established for each native community type found in the mine area.

2. The revegetated areas and their respective reference areas will be evaluated for at least two consecutive years prior to application for bond release and shall include the last two consecutive years of the bonding period. Application for final bond release may not be submitted prior to the end of the tenth growing season.

3. These operators shall initiate a study approved by the department which will demonstrate that the revegetated areas are capable of withstanding grazing pressure.

4. The stocking of trees, shrubs, half-shrubs and the ground cover established on the revegetated area shall be comparable to the stocking and ground cover on the reference area and shall utilize local and regional recommendations regarding species composition, spacing and planting arrangement. The stocking of live woody plants shall be comparable to the stocking of woody plants of the same life form on the reference area. When this requirement is met and acceptable ground cover is achieved, the 10 year responsibility period shall begin.

5. The operator shall utilize seed and seedlings genotypically adapted to the area when available in sufficient quality and quantity.

6. Where tree species are necessary the permittee shall plant trees adapted for local site conditions and climate.

7. The permittee shall consult with appropriate state and federal wildlife and land management agencies and shall select those species that will fulfill the needs of wildlife, including food, water, cover, and space. Plant groupings and water resources shall be spaced and distributed to fulfill the requirements of wildlife.

8. Weighted productivity shall be determined for each of the following morphological classes; annual grasses, perennial grasses; annual forbs; biennial and perennial forbs; and shrubs. The production of each class on the revegetated area shall be comparable to the weighted production for that morphological class.

9. The number of species occupying 1% or more of the ground cover in the revegetated area shall be equal to or greater than the number of species occupying 1% or more of the canopy cover in the reference area.

The above is only a brief introduction to the many challenges facing the land rehabilitation profession. Also keep in mind that similar requirements must be implemented by most states, otherwise OSM will implement their own Federal program.

To date in Montana, we have made excellent progress towards developing techniques for establishing stands of native grasses. Our present "state of the art" can enable us to establish native grass stands which comply with the new standards. However, I feel we are still in the dark ages when it comes to reestablishing suitable stands of native forbs, shrubs and trees. I will comment on five areas of work which will require added effort if we are to comply with the new land rehabilitation standards.

1. Ten years of revegetation research in Montana has shown that many native forb, shrub and trees cannot be successfully established if seeded with grass species. Many of the natives are difficult to establish from seed if competition from other species is not reduced or eliminated. If direct seeding techniques are not successful and the species are required for successful land rehabilitation, then transplanting techniques must be implemented. This requires that large quantities of high quality native plant species not commonly available will need to be produced. This is not an easy task because many of the most desirable species do not readily lend themselves to present day propagation and production methods. Persons entering this field will require a substantial amount of information and training regarding individual species characteristics. Management methods necessary to produce native plant materials will become more complex. Most native plant production will require long-term contracts to insure production of the required number of each species, to specify plant sizes, to designate source of parent material and to insure proper delivery time. Presently within the intermountain region there are several nurserymen producing native plant material for large scale land revegetation. Although these businesses have had their share of problems they are expanding these services and will be capable of supplying plant material not available from other suppliers.

2. A second area requiring additional effort is that of developing efficient handling and planting methods for large numbers of plants. Although transplanting of bare rootstock has been successfully practiced for many years, it is labor intensive, produces variable establishment rates and has resisted total mechanization. Presently this method is considered inadequate for large scale revegetation projects. Recent emphasis on development of containerized transplant stock for reforestation and land revegetation has resulted in a wealth of new techniques and materials. Much of this work directly applies to our need to establish native species on mine spoils.

Containerized planting system development has resulted in numerous container types and propogation methods. I believe it is still too soon to make final decisions as to which systems are most suitable. All these innovative systems must be intensively field tested to determine advantages and disadvantages. Most likely there will be no single type and size of container propagation method and planting procedure which is best for all conditions. More cooperative research and system evaluation is needed to help define what methods perform best under specific conditions.

At Montana State University we have concentrated our efforts on developing what we call the dryland tubeling (Jensen and Hodder, 1979). This method was developed primarily for establishing shrub and tree species in semiarid harsh environments. The 2 inch diameter by 24 inch long paper and plastic container is designed to position the root system of a well developed juvenile shrub or tree deep in the soil where soil moisture is more readily available and where root system competition is reduced. This method has proven successful in semiarid eastern Montana. We have now progressed to the point where planting is completely mechanized. Working in cooperation with the Missoula Equipment Development Center (U.S. Forest Service) a machine has been developed which will plant a dryland tubeling within a one minute cycle time. The machine attached to a tractor's 3 point hitch, is basically simple in design and should prove to be highly reliable. We hope to have this machine perfected to enable manufacturing by the spring of 1981.

3. Earlier I mentioned that direct seeding of many native species has not proven highly successful. However, this does not mean there is not or will not continue to be a need for seed of native plants. Presently the demand for native plant seed greatly exceeds the supply. Large quantities of native grass and forb seed are being produced on agricultural lands and harvested from native stands. With the implementation of the new land rehabilitation standards demand for native seed supplies is bound to increase at an exponential rate. Presently there is urgent need to have more seed grown or collected within a reasonable distance of the major soil disturbing projects. Also smaller quantities of seed for site specific species will need to be collected for the propagation of the required transplant stock. In short, a need still exists for more people to be involved in native seed production and collection.

4. A fourth area requiring additional work by land rehabilitation professionals is that of developing improved methods and capabilities for salvaging and reestablishing mature native plant materials. Land disturbances destroy vast quantities of native plant material that is irreplaceable by conventional standards. In areas such as eastern Montana, development of mature shrubs and trees may require 10 to 20 years. Destroying such material is an unexcusable waste if methods are available to salvage and reestablish the vegetation. Salvaging mature trees and shrubs with the tree spade is becoming a routine practice at many strip mines in Montana, Wyoming and Colorado. In recent years transplant survival rates have improved because handling techniques have been refined, species requirements are becoming better known and above-ground plant size is being balanced in relation to rootball size. Research and development work completed at Montana State University has produced two methods of salvaging and reestablishing shrubs. One method referred to as rootpad transplanting involves preparing the shrub for transplanting by first mowing the tops off the shrubs to within approximately 4 inches of the soil surface. A large capacity front-end loader is then used to carefully excavate at a depth of approximately 12 inches by scooping horizontally underneath the rootpad until the bottom of the bucket

is covered. The shrub pad is lifted and transported to the planting site. The bucket is gradually tipped as the loader moves backward, thus sliding the rootpad off the bucket and into the planting depression. Following unloading of the shrub rootpad, topsoil is filled in around the edges of the pad and into all cracks that developed while unloading. The soil can be pressed in place by running a light rubber tired vehicle around the perimeter of the pad or by packing with the bottom of the bucket. Rootpad transplanting establishes masses of shrubs such as native snowberry and rosebush within one year of transplanting. This method is excellent for landscaping around rest areas or for establishing erosion resistant vegetation in drainage ditches. The second method of transplanting shrubs is called shrub root sprigging. This method was developed to use rhizomatous root systems capable of withstanding disturbances. Root sprigging is generally used for planting large areas of low density plants. The first step in root sprigging is to locate sources of desirable plant material on terrain suitable for equipment operation. Next a flail or rotary type mower suitable for cutting brush is used to remove top growth to within approimately 4 inches of the soil surface. The remaining top growth and rhizomatous root systems are then excavated with an agricultural type plow or similar implement and a front-end loader. No effort is made to keep the roots and soil consolidated. The root-soil mixture is then trucked to the planting site where it is uniformly spread over the planting area. The root systems are then completely covered with approximately 4 inches of good quality topsoil. An improved method of shrub sprigging is presently being developed by Montana State University, Reclamation Research Unit and the Vegetative Rehabilitation and Equipment Workshop. A machine, similar to a potato picker has been designed to separate root systems from the soil. The root systems are loaded directly into a modified manure spreader which is used to transport and spread the roots over the planting area. A scraper then covers the root systems with 6 inches of topsoil.

Both shrub root sprigging methods have established excellent stands of the shrubs, woods rose and common snowberry on roadside and on mine spoil research plots. This method can be easily implemented using commonly available construction equipment or the more recently developed root harvesting machines. Implementation of this technique should prove useful for rapidly stabilizing critical drainage areas with an erosion resistant stand of shrubs.

Progress is being made toward the ultimate goal of salvaging and reestablishing all desirable native plant material before an area is disturbed. However, I believe we have only scratched the surface toward what can ultimately be accomplished in this area.

5. A fifth area of importance is the need for a program emphasizing information exchange and continuous education. In order for professionals and businesses to attain up-to-date expertise and maintain a high level of performance in this rapidly progressing science a strong self-education program must be implemented. It is the responsibility of every professional to seek the latest in technology and to inform others of their capabilities. The above needs can be partially fulfilled by attending professional meetings, reading professional publications and exchanging ideas with other progressive scientists and businessmen.

SUMMARY

In summarizing what I have commented on it becomes clear that the role of nurserymen and related professionals must be expanded to include rehabilitation of disturbed lands. These people will ultimately be expected to provide many of the services required to meet the new reclamation standards. Personally, I believe you are entering a challenging era which will provide profitable business opportunities for those willing to pursue land rehabilitation projects.

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IMPACT OF DESERT FORESTRY ON THE PLANT MATERIALS SYSTEM OF NEVADA[1]

Matthew Frolich[2]

ABSTRACT

The desert forestry program in the State of Nevada has given rise to several problems at the nurseries. This paper explains the background of the major problems and suggests possible means to mitigate them.

INTRODUCTION

The development of desert forestry as a new concept in the plant materials system is bringing about basic changes in the state nurseries. These changes are being manifested in management, production and customer relations. The most important changes and their relationship to physical conditions and policy are considered in the text. Solutions or mitigating programs are also considered that show some promise for management.

WHAT IS DESERT FORESTRY?

Nevada can be described as the driest state in the United States. It is almost entirely within the Intermountain Basin, the landscape being largely characterized by Sagebrush, Greasewood and Pinyon-Juniper types. Small wonder that the state found it necessary to define a kind of forestry that could be workable in this arid land. Our 1975 Legislature defined desert forestry as "the science of developing, caring for or cultivating conservation plant materials in an environment by modifying their response to adverse growing conditions while minimizing the consumptive us of water." I am sure you can readily see a couple of potential areas for action in carrying out the thrust of the definition.

How can the response of plant material be modified to adverse growing conditions? The only practical ways that are available to us now are pruning and the use of films to reduce transpiration. Any problem in desert forestry that follows this path, however, will be highly restricted as the costs are quite high.

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[1]Intermountain Nurseryman's Association, Boise, Idaho, August 14, 1980
[2]Nursery Coordinator, Nevada Division of Forestry, 201 South Fall Street, Carson City, Nevada 89710

Minimizing the consumptive use of water opens a wide, promising avenue in the selection of adapted species. This particular field not only presents us with a wide number of choices, it also presents us with an attainable goal. There is no doubt that this is our greatest potential, but a serious set of problems emerge that have an effect on our nursery operations. Following is a consideration of those problems on the nurseries that supply conservation plant materials.

THE GEOGRAPHY OF NEVADA

The problems we have found in matching the thrust of desert forestry to our plant materials program are closely tied to geography. A brief look at the conditions found in Nevada will be enlightening.

Nevada is characterized by a wide variety of geographical conditions. A look at the map will show you why. The north-south distance is about 475 miles, each to west about 375 miles. In this expanse we have elevations from 500' to 13130' above sea level and a multitude of mountain ranges in a more or less north-south orientation. Each mountain range has a moist side and a dry side. The valleys usually have closed drainage systems with dry lake beds and considerable areas of alkaline soils.

Strong winds are found everywhere in the state. Periodically, winds in excess of 100 miles per hour are reported in northwestern Nevada. Abrasion of plant tissue by blowing sand (or ice crystals) is not unheard of. Wind can also do strange things to nurseries; a consignment of containerized ornamental plants lost 90% of light soil mix in the containers in one afternoon of wind in the Carson City area.

Temperatures cover a wide spectrum. A portion of our state extends into margins of the Sonoran Desert along the lower Colorado River. Here the coldest temperatures may be 25°F or above. In fact, at Laughlin, Nevada there are some decendents of the original date palms introduced into the United States. The northeastern part of the state has the other extreme - low temperatures with a protracted winter. In between we can find almost everything else. In western Nevada storms blow off the mountains at any time of the year. Late frosts are commonplace. Diurnal temperature fluctuations in excess of 60°F occur in July and August in the northern area, fluctuation in the south at the same time may be only a few degrees.

Precipitation may be as little as 2 inches per year on the eastern slopes of the mountains to more than 40 inches at the upper elevations on the western slopes. Evaporation rates vary from 36 inches in the western mountains to 82 inches in the southeast and pose a very special problem in establishing plant materials. It is pretty close to miraculous when plant material is established with 2 inches of rain, summer temperatures in excess of 110°F, intermittent winds carrying abrasive sand and an evaporation rate of 82 inches!

It is no wonder that desert forestry has had an impact on the plant materials system. To fulfill the directive of the law, a large number of species and selections will have to be screened to find those suitable for each of the many specific geographical locations within the state. Those that are successful will be incorporated into the production schedules of the nurseries. Record keeping will have to be increased and more importantly to the nurseryman, propagation and growing facilities become more complex.

THE ROLE OF THE FORESTERS

Those of you who are managing forest nurseries are already working closely with foresters in the field. They recognize and select the genetic material that is to be used for reforestation programs in their districts. The cones are collected and delivered to you and it is then your responsibility to clean and store the seed to produce plant material on their demand. The nurseryman who is growing windbreak material for the general public, on the other hand, has a lot of fun trying to outguess his market. Fortunately, many of the species are standard and can be used over a wide area. The introduction of new selections for specific sites, though, cannot be done by the nursery manager. Field personnel become an integral part of the nursery be assuming a role similar to the forester in selecting genetic material for the nurseries.

The service forester as an active agent of the nurseries will assume a certain amount of control over nursery management. The responsibility cannot be taken lightly if the program is to succeed. This person must be aware of the many parameters imposed by specific sites and must recognize those plant species that will enhance the chance of success in the program. He must also monitor the plantings over time to build stability into the plant materials program. Long term success is not built on the capricious addition or deletion of plant species in the production schedule.

A second vital function that must come from the field is the estimates of plant materials needed. Plant production far in excess of need is not economical and too few may not accomplish what the forester wants to do.

THE NEW NURSERY

As the desert forestry has developed in Nevada, six major problems have emerged. They range all the way from internal changes in management to dealing with the clientele.

A problem has developed in management that is rather extensive. Mention has already been made about the role of field personnel in selecting and designating quantities of material needed in the program. It is difficult enough for one person to set budgets under an enterprising system, let alone widely dispersed individuals. We find that there is a reluctance on the part of the newly enlisted field personnel to set targets for production and sales. This imposes a certain amount of adroit footwork upon the management to meet the budget requirements as set by the oversight agencies of legislature and administration.

The nursery operations themselves have revealed four problems. One is the seed bank. Many of the species that will be introduced will be collected from the wild. Arid land plants are notorious for erratic seed production, some only setting crops at intervals of 10 years or more. Storage of this material to keep it viable is very often on a hit or miss basis. There will be erratic production of native plant species until a reliable source of seed is obtained or until storage proceedures have been worked out for the difficult subjects.

The second problem in nursery operation is closely related - propagation. We simply do not know the requirements for successful germination of some of these species. Shortages of certain species can be anticipated simply because we have not provided the conditions necessary for germination and growth.

Thirdly, a wide spectrum of plant material imposes an economic problem on production . There are so many different plants requiring their own growing conditions that the greenhouse beds are fragmented. We cannot as yet predict very well the time required for production of all species of plants handled by our nurseries.

The last problem we have encountered revolves around our decision to produce in containers. We have selected a container that is cheap, of adequate size, but not very durable. Distribution of nursery stock has become a problem because of the weight involved. Thus far we have been keeping the light weight soil additives at a minimum because of the clay soils we have encountered in the planting sites. Heavy trucks are necessary for transporation to distribution points in the state.

Our only problem we have encountered in dealing with the clientele is one of timing. Containerization has lengthened the planting season, but the typical customer wants to plant in the spring. Monetary restrictions forbid the construction of extensive nursery equipment to enable the program to exist on spring sales alone.

CAN ANYTHING BE DONE TO EASE THE IMPACT?

The nursery manager, like everyone else finds it very easy to list the woes that accumulate from a new program. The responsibility of the manger is not to stop there, but to proceed with the program, solving those problems so as to bring the new program into existence. We can draw from our experience and propose some proceedures that could be employed in the early planning period that would have made our change-over easier to accomplish.

Of course, the uppermost question is "how can this program be implemented?" And, of course, no answer can be found without understanding. A definition is needed that is clearly understood and agreed upon by the policy makers, administration, oversight agencies and the action agency that clearly defines the mission and the limits of the new proposal.

After this agreement has been reached, the action agency should embark on an investigative program that has the thoroughness of a systems analysis. After all, the manager of the action agency is the person who is supposed to do the budgeting and the time frame reference for the project. He simply cannot institute a complicated program without having the best information possible. Admittedly, no one has succeeded in gathering all of the information about any project, but mistakes in committment are inversely proportional to the body of knowledge.

Management must make accurate estimates of the resources needed to accomplish the mission. The manager must justify the expenditure of funds to obtain the necessary equipment and the necessary positions. Do not forget that the cost of training is as much as part of development as is the cost of a new greenhouse.

Position descriptions and responsibilities must be clarified early in the program. Once the level of responsibility and area of responsibility of each actor is understood, many of the problems of management are mitigated. Personnel management must be based on who is responsible for what.

Pursue the course of action with deliberation. The addition of too many activities and functions in a short period of time results in confusion, hard feelings and the inevitable delay. There will be problems that crop up that no one could anticipate. When time is planned into the change over period these can be handled without becoming crises.

For the internal problems of production, remain flexible. Add or subtract species in the production schedule only with good justification. Use small units for seed treatment and germination so that specific growing conditions can be provided. Keep equipment as "general" as possible. The nursery will have to supply small quantities of plant materials for specific uses.

Consider seed orchards as an integral part of the nursery. Control of seed collection and production would be concentrated and more easily facilitated. A higher production of seed would be anticipated and that would reduce storage problems.

Integrate a distribution system with the necessary transport within the nursery. The initial cost may be high, but the loss of some management decisions to the field personnel can be made up in part by better distribution. Plant losses are at a minimum if the responsibility of distribution rests with the nursery. The weight problem may be mitigated as more knowledge is gained about the planting sites.

It will not be easy to change the habits of the clientele. We are now developing an informational program to show the advantages of planting at different seasons of the year. For Nevada, we really need three programs, one for each of the major areas. Eventually, the plant materials program, through the field personnel will become a positive benefit to the people of the state.

Evaluations will have to be frequent and honest. The final criteria for success will be determined by the clientele of the program.

NURSERY MANAGEMENT INFORMATION SYSTEM[1]

Thomas E. Williams[2]

ABSTRACT

In 1978 a committee was established to prepare a proposal for automating and standardizing current nursery record-keeping and report preparation procedures. The system is designed to generate reports and document the history of seedlings and their treatments from seed to established seedlings. Based on the committee work over the past three years and the pilot testing conducted at the Fort Collins Computer Center (FCCC) we propose to implement this system on microprocessor equipment located at each nursery handling a significant volume of business.

The paper presented at last year's Intermountain Nurseryman's Association Meeting summarized the initial steps toward developing a national Nursery Management information System. This paper will outline the activities which have taken place since that time.

The current nursery volume of business plus predicted increases in the future demonstrate that efficient nursery management is contingent on developing a automated system of managing data, generating report and providing historical records.

The initial efforts toward achieving this objective began in 1978 when a committee composed of representatives from Regions 2, 3, 5, 6, 9 and WO-TM met at Fort Collins to prepare a proposal for developing a Servicewide Nursery Management Information System. This proposal was sent to all Regions for their assessment of compatibility with their operations. After evaluating the Regional responses our committee prepared a feasibility report which designated Medford and Wind River Nurseries to participate in a pilot test of the system. To demonstrate the need for an automated system all Regions supporting nurseries were contacted regarding their present and expected volume of business in 1985. Their responses indicated that by 1985 we can expect a 250% increase in number of seed lots grown and a 175% increase in the number of shipping transactions per year.

To further assess the need for an automated Nursery Management System the objectives listed below were addressed during the pilot test.

1. Accurately storing and retrieving large amounts of information.

2. Personnel saving (more efficient use of people).

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[1] Paper presented at the Intermountain Nurseryman's Association Meeting, Boise, Idaho, August 11-14, 1980.

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3. Timely response to reporting requirements and special queries.

4. Historical records for evaluation of past practices and to "track" stock problems.

5. Establish more effective communications between nurseries.

6. Tie seed and tree performance to land treatments and nursery practices.

7. Refinement and improvement of nursery sowing factors.

Coincident with the pilot test at the two nurseries, FCCC personnel have been working with Medford Nursery personnel in developing draft Field Data Forms. One of these - the Seedling Request Form - has been sent to the field for use in ordering seedlings this year.

Seedling history data from Medford and Wind River nurseries have been entered, edited and loaded into a S2K Data Base which allows us to gain experience with the capabilities of the system.

Most of our recent activities have been with the seed analysis portion of the NMIS. The number of required input and output records have been defined and the logical data structure completed for the seed. This logical data structure will be used in the development of the seed Field Input Forms.

FCCC personnel have analyzed the results of the pilot test conducted at Medford and Wind River nurseries using the Fort Collins computer and the consensus is that a microprocessor located at individual nurseries would best satisfy our needs. This decision was arrived at primarily because of the following concerns:

1. Nursery personnel were, and still are, required to come to work before normal working hours or to remain after normal working hours in order to gain access to FCCC.

2. Due to poor communication facilities at the nurseries, nursery personnel found it difficult to stay connected to the Fort Collins computer for long periods of time.

3. There is no easy method of generating and/or receiving formated reports (5 to 50 pages) at the nursery.

Two additional factors were considered in arriving at this decision to use microprocessor equipment.

1. The system is a recordkeeping and reporting system and does not require sophisticated analytical tools.

2. No one except nursery personnel need access to the nursery data except in the form of reports.

Our initial assessment of costs comparing the manual system, use of FCCC and using a microprocessor indicate the most efficient system to be the microprocessor.

The decision to go with a microprocessor was followed by another cost compariso between two brands of equipment, the TRS80 Model II by Radio Shack and the DS990 Mode I by Texas Instruments. The NMIS could be implemented on either microprocessor. A significant cost differential exists between the two types of systems, however, we propose to go with the DS990 System at an initial cost of almost double the TRS80 Model II System, for the following reasons:

1. Procurement under the current Departmental Contract gives a better foundation to work from if any vendor related problems occur.

2. Purchase of Texas Instrument hardware will allow us to participate in and benefit from standardization of equipment and training within the Forest Service.

3. Texas Instrument has more experience in the development of production orien ed hardware than Radio Shak - Tandy Corporation.

4. Procurement time is faster under existing Department Contract.

5. A formal training package for operation and programming on the Texas Instru ment equipment will be available.

6. A good Data Entry Language exists for the DS990 equipment.

7. The DS990 system allows for index sequential files.

Where do we go from here? Prior to the system becoming operational the following activities need to be addressed.

1. Acquisition of hardware.

2. Preparation of software.

3. Preparation of final field input forms.

4. Provide training for personnel using the microprocessors.

5. Conduct meeting with Regional and Nursery personnel to demonstrate and explain the system.

6. Prepare implementation schedule to determine order in which other nurseries will acquire the system.

Our target date for system implementation mentioned at last year's meeting has been delayed somewhat due to accessibility of hardware and software, however, we hope to have the entire system with documentation operational by 1/1/81.

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The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

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HARVESTING AND UTILIZATION OPPORTUNITIES FOR FOREST RESIDUES
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FOREWORD

Timber utilization practices have improved dramatically in recent years, but there is still a large volume of unused wood residues and salvageable material in the Rocky Mountain area. The need to achieve more complete and efficient utilization of this resource poses a major challenge. National projections predict substantial continued increases in demand for wood and wood fiber-based products. Environmental considerations also favor extending (or at least maintaining) the use of wood, a renewable natural resource that can be processed with less energy and less attendant pollution than alternate materials. Increasing interest in biomass fuels for supplementary power generation further emphasizes the undeveloped potential of the wood residue resource.

Excessive volumes of forest residues result in significant management problems, creating a fire hazard, inhibiting wildlife use, detracting from esthetic quality, interfering with regeneration, and requiring costly disposal treatments. Harvesting and utilization practices that facilitate more complete use of these residues can help meet national needs for wood products, and solve critical forest resource management problems.

Research reported in this Symposium investigates alternative timber harvesting and processing practices that can achieve more intensive timber utilization. Major subjects include detailed evaluation of the resource; investigation of product, processing, and market opportunities; and development of harvesting and handling methods. University researchers have been deeply involved as collaborators in all aspects of the research program.

Most of the research has been conducted in the lodgepole pine, larch, and Douglas-fir forests of Montana, Idaho, and Wyoming, and within the economic and industrial context common to that area. Investigations have covered an array of resource and operational situations, and have emphasized harvesting and utilization alternatives appropriate for old-growth, unmanaged stands. The results have broad implications for utilization of softwood species in general.

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ABSTRACT

The full utilization of residual material left in the woods following logging and thinning operations, and disease, insect attack, and windthrow has long been a source of concern and frustration to the forest manager. Recently there has been tremendous interest in increasing the use of residuals to combat projected energy and raw material shortages. The economics of harvesting increased levels of residuals must receive careful scrutiny. While many recovery ideas may be technologically and biologically possible, all utilization ideas will have to undergo thorough financial evaluation and will have to measure up against alternative uses of monies.

KEYWORDS: wood residues, residue utilization

Wood residuals by definition are what is left after valuable products have been removed by harvesting or manufacturing processes. It has been called slash, unmerchantable stem and branchwood, cull logs, foliage, and roots by the logger, and slabs, edgings, chips, sawdust, bark, and hogfuel by the mill manager. By its nature it has been viewed more as a problem to be dealt with than as an opportunity to be exploited.

The full utilization of residual material left in the woods following logging and thinning operations, and disease, insect attack, and windthrow has long been a source of concern and frustration to the forest manager. Recently there has been tremendous interest in increasing the use of residuals to combat projected energy and raw material shortages.

When asked to prepare this paper, I obtained a computerized listing of the literature available on wood residuals. The utilization of residuals has received much attention. A quick review of some of the subjects addressed in relation to

residuals easily shows just how broad the subject really is. Some of the subjects are familiar, many are new: whole tree chipping (WTC), stump puller, pollution, fuel-energy, synthetic crude, biomass energy machine, gasohol, chemicals, ethanol, site deterioration, livestock feed, bread additives, mulch, and firewood. All of these subjects represent projects either underway or slated for future research.

Forest Industries magazine has recently instituted a monthly section on wood energy as it pertains to the use of sawmill and logging residuals. A sample of other articles concerning the use of or possible use of residuals is as follows:

- Missoulian - October 28, 1979, "Can a Wastewood put Dinner on the Plates?"
- Tobacco Valley News - Eureka, Montana, "Mills More Efficient."
- Across the Board - October, 1979, "Gasohol."
- Timber West - October, 1979, "Firewood Cut Increases 75%."
- The Logger and Lumberman - October, 1979, "Speak Out." (an editorial)

From the number and variety of these articles it is apparent that wood residuals represent a high-interest area to a broad cross section of our population.

My own perspective on residuals has been shaped by over 30 years of forest management and logging experience in the Northern Rocky Mountains, for the most part, in Montana. During these three decades the use of wood residuals has increased in both harvesting and manufacturing activities. In order to provide some background to our program, I would like to outline some of the changes that have taken place and some of the reasons they came about.

One of the most important changes, which led to greater utilization of timber, was the construction of stud mills in the 1950's and early 1960's. These mills permitted the logging of previously undesirable stands of lodgepole pine and other whitewood species. Incidentally, the advent of a dependable power saw around 1950 probably had more to do with increasing utilization than any other factor. By using a power saw, a faller could make the many extra cuts required to manufacture logs from smaller timber, and do it quickly and efficiently. Cross-cut saws were retired with few mourners, especially among those poor souls who had to use them.

Minimum merchantability requirements for trees and logs decreased over the years until today a minimum merchantable tree is 7-or 8-inches in diameter at breast height (d.b.h.), and a minimum merchantable log is 8 feet in length to a 6-inch top. These new merchantability requirements have significantly reduced the volume of residuals remaining after the logging operation.

Another large change in the use of "waste" wood in the Missoula area occurred when a pulp mill was constructed here and commenced operation in 1957. As a result, sawmill residuals, slabs and edgings that were formerly burned in tepee burners were suddenly being converted into profitable pulp chips. The decrease in the number of tepee burners, with the resultant decrease in air pollution, was noticed immediately.

Planer shavings were the next residual product to be utilized when, in the late 1960's and early 1970's, particleboard plants were constructed both in Missoula and Columbia Falls, Montana. These plants used planer shavings as the main material in their particleboard and so, once again, industry had increased the use of residuals from lumber and plywood operations.

The use of hogfuel, which is produced by grinding up bark, has steadily increased in all forest product facilities. Some of the hogfuel is used for the production of steam, and the steam is used in drying lumber and plywood, in driving machinery, and in heating buildings. A wood products firm in Libby, Montana, uses hogfuel to produce steam that, in turn, is used to generate electricity. That company uses a portion of the electricity for its own use and sells the surplus to the local power company.

Pulp mills have now developed processes that permit the use of a percentage of sawdust in the pulping process. This further reduces the volume of sawmill and plywood plant residuals. In fact, we're rapidly approaching the point in the use of manufacturing residuals that we have "even used the squeal of the hog."

There have been two short periods in the past ten years when local pulp mills used roundwood for chips. These logs were cull for lumber or plywood, but had enough sound material to use for chip purposes. Undoubtedly the time is fast approaching when roundwood will be a permanent source of pulp mill furnish.

A public utility in Washington recently conducted feasibility studies to determine if it is practical and economical to build a steam electrical generating plant which would use hogfuel as its energy source. The tentative location of the plant would be in the eastern part of the state of Washington.

I think it is important to point out that the increased use of residuals has been possible due to new or changed manufacturing facilities that could economically use these residuals. It is evident that any proposal to increase the use of residuals must be economically favorable to the user or manufacturer, or else it will not occur.

So, it is apparent that the use of residuals has increased dramatically in the last 30 years, and it is obvious from the size of this conference that there is a great deal of interest in how to further increase residual utilization. At the same time, there are still many questions to be answered before we commit ourselves to even greater use of residuals. To me, some of the more important questions would be: What are the biological limits of residual removal? If more of the biomass is removed during logging operations, what effect will this have on site quality and site potential? Should a portion of all residuals be left on the area to return to the soil? Will the removal of more logging residuals have a detrimental effect on future growing capacity?

We also need to develop technology to permit the economic removal of more of the residuals. In my opinion, most of the future increase in residual volumes will come from noncommercial thinning operations. Presently, we do not have the technology to use these thinnings, particularly on steep slopes.

Another important area to consider is the political implication of more residual use. It would appear that the general public would heartily approve of the use of more residuals. However, we must fully explain to all publics what the removal of more residuals will entail.

Finally, the economics of harvesting increased levels of residuals must receive careful scrutiny. While many recovery ideas may be technologically and biologically possible, all utilization ideas will have to undergo thorough financial evaluation and will have to measure up against alternative uses of monies.

THE FOREST RESIDUES UTILIZATION R&D PROGRAM

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ABSTRACT

Since 1974 the Intermountain Station has directed an integrated program of research toward developing methods to achieve more efficient timber utilization, consistent with responsible management of the forest ecosystem. This research combines the efforts of scientists in utilization, engineering, economics, marketing, and the biological sciences. Research in residue characterization has defined the volume, character, and product potential of residues in various timber types and harvesting situations. Research in products, processes, and markets has included work relating to solid wood and chip and fiber products. Particular emphasis has been given the processing and use of dead timber, by far the largest residue component in the Intermountain West. Other research has explored the feasibility of achieving closer utilization with conventional cable and ground skidding harvesting systems under different silvicultural and management prescriptions. Related research is developing new harvesting system concepts and practices, with emphasis upon systems that can function more efficiently in handling small timber, residue material, and small volumes per acre. More efficient utilization of the wood resource represented by forest residues can substantially extend the resource base.

KEYWORDS: forest residues, wood utilization, timber harvesting, forest practices

FOREST RESIDUES--PROBLEM AND OPPORTUNITY

A major challenge in the Intermountain area is the need to achieve more complete and efficient use of our available wood resource. Although utilization practices have improved dramatically in recent years, the aggregate volume of unused residues

and potential salvage material is still very large. There are two immediate and related needs. The first need is to improve the recovery and utilization of the total wood resource, leaving less material as residue. National projections predict substantial increases in demand for wood and wood-fiber-based products, especially softwood housing construction materials. Environmental considerations also favor extending (or at least maintaining) the use of wood, a renewable resource that can be processed with less energy and less attendant pollution than alternative materials. Harvesting practices that facilitate more complete utilization of the available wood resource in the Northern Rocky Mountain States can contribute significantly to meeting this demand.

The second and concurrent need is to reduce the adverse esthetic and environmental impacts of timber harvesting, associated road construction, and other onsite activities. Present utilization standards and logging practices leave large amounts of residue--small trees, cull and broken logs, tops, and dead timber--on the ground following harvesting operations. Road right-of-way clearing and thinning operations result in additional volumes of unused wood. These residues can contribute to the forest's nutrient reservoir, reduce erosion, protect seedlings, and provide wildlife cover. In the quantities that frequently occur, however, they create a fire hazard, inhibit regeneration, detract from area esthetic values, and represent waste of a scarce fiber resource. Harvesting and transportation practices that improve the economic feasibility of using more of this material can remedy a major source of undesirable impacts on the area.

Since 1974 the Intermountain Experiment Station has directed a coordinated program of research, the Forest Residues Utilization R&D Program, toward investigating alternative timber harvesting practices that may facilitate more intensive, environmentally compatible, timber utilization. Major objectives of this program have been:

(1) To develop resource information--present and predicted--defining the location, quantity, and physical characteristics of material considered residue, as a means of strengthening utilization opportunities;

(2) To evaluate harvesting and transportation systems that can improve the technical and economic feasibility of recovering and using more of the total wood resource;

(3) To evaluate product, process, and market alternatives that will facilitate more complete and efficient use of material commonly left as residue;

(4) To evaluate the biological and environmental effects of residue reduction, and the influence of residue reduction on postharvest forest management needs and activities.

The principal subjects of this report and of the "Harvesting and Utilization Opportunities for Forest Residues in the Northern Rocky Mountains" symposium are the first three areas of investigation--research and related industrial experience in resource evaluation, harvesting, and utilization. The fourth area, environmental and management consequences, was the subject of a separate symposium in September 1979 (USDA Forest Service 1980).

THE RESEARCH PROGRAM

To meet specified objectives, program research has necessarily involved a wide variety of subject matter and associated disciplines. The core program staff has included researchers with skills in engineering, wood technology, economics, meteorology, microbiology, entomology, and biometrics. Other Station research work units in such subject areas as silviculture, fire management, economics, hydrology, and wildlife habitat have participated extensively in studies of biological and management impacts. Other major participants in the research have included researchers at other Forest Service units, researchers at several universities, and industrial timber harvesting and processing firms in the region. The Bureau of Business and Economic Research, University of Montana, and the forest products industry are especially worthy of note because of their extensive involvement.

Early program planning was developed around three basic concepts: recognition that wood utilization objectives and practices must extend from, and be compatible with, broad forest management objectives; belief that the best approach to residue utilization is through more efficient initial harvesting practices, rather than salvage operations; and recognition that residue reduction has significant and direct effects upon the forest ecosystem and subsequent management activities. The typical procedure followed in planning and implementing program research is illustrated in figure 1. First consideration was given to defining the total forest resource management objectives for a particular timber stand and site situation. Harvesting specifications were then developed for tree removal and other stand or site character modifications (usually an array of possible alternatives) to meet management objectives. Harvesting systems, utilization levels, and postharvest treatments that could achieve the selected treatment effects were applied. Finally, technical and economic feasibility were evaluated, and the environmental and management consequences of tested alternatives were determined. A central concern, of course, was to apply and test harvesting alternatives that have the capability of recovering much of the wood material commonly left onsite as residue.

Assessing the Resource

The term "forest residues" is commonly applied to all woody material that for one reason or another remains in the forest. Major components of this residue resource in the Northern Rocky Mountain area are: (1) logging slash and cull material from harvested trees; (2) standing and down dead timber; and (3) submerchantable trees cut in the process of thinning, postharvest site treatment, or right-of-way clearing. For most primary raw materials, the term "residues" implies an unusable waste byproduct. By contrast, wood residues have the same basic physical and chemical characteristics as the primary resource and are differentiated only by size, shape, or condition. They can be used (within the limits imposed by size, shape, or condition) by the same sawmill, pulpmill, or particleboard plant that uses the so-called "merchantable" part of the resource. Residue is simply that part of the total wood resource that cannot be used at a given time, because of constraints imposed by technology or economics--largely economics.

A first step in evaluating the utilization potential of the residue resource is to develop some estimate of quantity and physical characteristics. Although an accurate assessment would be extremely difficult, expensive, and probably not warranted, reasonable estimates are needed and have been obtained through various inventories and studies. A brief review of some of these inventory figures will serve to illustrate the scope of the residue resource.

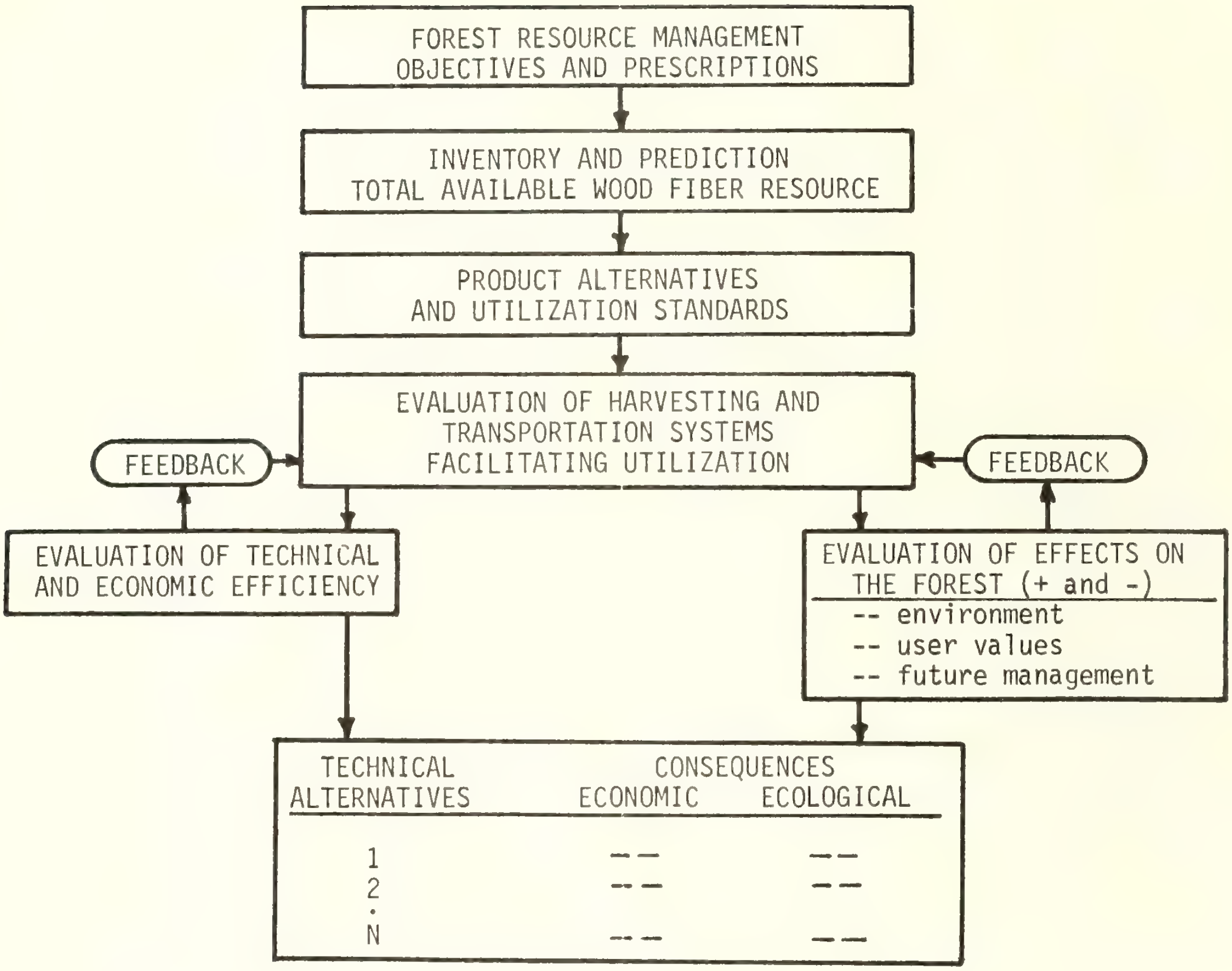

Figure 1.--Research program schematic depicting sequence of key phases. The program emphasized developing and testing harvesting and utilization alternatives that are compatible with, and facilitate, total forest resource management on the site.

The largest and most conspicuous residue component in Northern Rocky Mountain forests is dead timber (fig. 2). Dead timber, resulting largely from a long and continuing history of insect and disease damage, can remain sound for many years on the relatively cold, dry sites common in this area. Forest Survey information indicates that approximately 6.7 billion ft^3 (190 million m^3) of salvable, dead sawtimber exists within the nine Rocky Mountain States (table 1). Montana alone contains an estimated 3 billion ft^3 (85 million m^3), roughly equivalent to 12 years' allowable cut at present harvesting levels. In addition, the annual sawtimber mortality for the same States is estimated to be 2.5 billion bd. ft. (71 million m^3), of which about two-thirds occurs in Montana and Idaho.

Figure 2.--Old-growth lodgepole pine stands contain a large proportion of dead material, both standing and down.

Table 1.--Net volume of salvable dead timber on commercial forest land in the Rocky Mountain States (source: Green and Setzer 1974).

State	Salvable dead timber Million ft^3	(Million m^3)	Percent of total
Idaho	940.0	(26.6)	14
Montana	3,000.7	(85.0)	45
Wyoming	577.1	(16.3)	9
South Dakota	47.0	(1.3)	<1
Arizona	133.4	(3.8)	2
Colorado	1,340.7	(38.0)	20
Nevada	10.4	(0.3)	<1
New Mexico	346.5	(9.8)	5
Utah	303.9	(8.6)	5
Total	6,699.7	(189.7)	100

Residues remaining after a conventional saw log harvesting operation include dead timber rejected as unmerchantable, slash and cull material, and small stems either accidentally or purposely downed (fig. 3). Recent research studies, discussed in some detail by researchers participating in this symposium, indicate volumes of residue ranging from 2,000 to over 4,000 ft^3 per acre (140-280 m^3/ha) (Benson and Johnston 1976; Foulger and Harris 1973). Residues remaining following conventional clearcut logging in old-growth lodgepole pine, for example, averaged 4,333 ft^3 per acre (303 m^3/ha) (Foulger and Harris 1973). Material 3 inches (7.6 cm) and larger in diameter accounted for 82 percent of the residue (table 2).

Figure 3.--Residues remaining following conventional saw log harvesting operations in old-growth stands frequently exceed 100 tons per acre (224 tons/ha).

Table 2.--Wood and bark residues remaining following clearcut logging to conventional saw log utilization standards in mature lodgepole pine--Teton National Forest (source: Foulger and Harris 1973).

Diameter size class		Residue volume					
		Wood		Bark		Total	
in.	(cm)	- - - - - Ft^3 per acre (m^3 per hectare) - - - - - -					
<0.3	(<0.8)	2.4	(0.2)	5.7	(0.4)	8.1	(0.6)
0.3-0.6	(0.8-1.5)	69.3	(4.8)	41.2	(2.9)	110.5	(7.7)
0.6-3.0	(1.5-7.6)	562.7	(39.4)	84.8	(5.9)	647.5	(45.3)
>3.0	(>7.6)	3,274.5	(229.1)	292.5	(20.5)	3,567.0	(249.6)
Total		3,908.9	(273.5)	424.2	(29.7)	4,333.1	(303.2)

Gross inventory figures do not imply that the entire residue resource is economically or physically available. Harvesting costs, access problems, and the randomly scattered nature of much of the resource are likely to limit economic availability indefinitely. Nevertheless, the figures indicate that with even slightly improved harvesting and utilization practices, the currently unused wood could provide a substantial basis for industry expansion and added product manufacture with no added drain on the timber supply.

Harvesting Research

Much of the research investigating the feasibility of intensive levels of wood fiber recovery was conducted on three primary sites. These include:

(1) The Coram site--typical of old-growth western larch/Douglas-fir stands on steep slopes.

(2) The Lubrecht site--dry site Douglas-fir, with intermixtures of ponderosa pine and larch, on gentle terrain; broadly representative of a major segment of the more productive commercial forest land in the region.

(3) The Teton site--typical of higher elevation old-growth lodgepole pine in the Central and Northern Rocky Mountains.

These study sites are described in detail, including harvesting systems and utilization standards tested, in this publication under "Intensive Utilization with Conventional Harvesting Systems" (Barger 1980). On these major sites, harvesting systems research was closely integrated with pre- and postharvest studies evaluating the biological and environmental consequences of intensive utilization. On a number of other sites, researchers cooperated with industrial logging firms to study the physical and economic feasibility of specific harvesting systems and practices (fig. 4).

Figure 4.--An experimental salvage operation recovers pole-size timber, establishing a measure of the costs and productivity of the practice.

Program research in harvesting systems has taken two directions--evaluation of the efficiency of existing systems and practices when used to achieve close utilization standards, and development of new harvesting practices and equipment better suited to handling smaller, low-value material. Field studies have included the use of in-woods chipping systems; use of conventional tracked and wheeled skidding equipment in relatively gentle terrain; and use of cable systems in steeper terrain. Low capital investment systems evaluated in small timber have included horse skidding as well as use of farm tractors (Host and Schlieter 1978). In each study, utilization prescriptions have generally extended from standard saw log utilization down to total utilization of available fiber.

The development of new systems has concentrated on systems for steep slopes, primarily smaller, more versatile cable systems. Of particular interest are systems that can reduce the density of roads; reduce sensitivity to road location; and gather or bunch smaller material to make larger yarding payloads. A number of these concepts are discussed at length in this publication under "Outlook for New Harvesting Technology" (Gonsior 1980).

Related research has been directed toward developing improved methods of evaluating proposed harvesting operations, laying out sale areas and units for cable logging, and evaluating economic operability. Determination of economic feasibility becomes more critical for high investment systems such as cable systems and whole tree processing systems, where substantial hourly amortization costs must be covered. The increased use of cable systems also requires greater care and precision in laying out sale areas, particularly in areas that are borderline in terms of topography and operability.

Products and Process Research

Program research in products and processes has been oriented toward defining product and process opportunities that can achieve economically viable utilization of forest residue material. The utilization of dead timber and small stems has received the greatest attention, because these components make up a large share of the residue resource. Forest residues include material that can be used for virtually every product manufactured from the merchantable timber resource. Given favorable economic conditions, material normally considered residue has been used for lumber, commercial poles, house logs, and a full array of products with less demanding specifications. Near-future opportunities for utilizing significant volumes of residue seem to be brightest in four basic areas: (1) extended utilization for conventional roundwood and sawn products; (2) use for pulpwood; (3) use for particleboard and fiberboard manufacture; and (4) use as an industrial fuel.

Practices that achieve extended utilization of residue for conventional sawn and roundwood products include revising sawtimber merchantability standards to accept smaller tree and log diameters, manufacturing lumber or treated products from older dead timber, and relaxing quality standards used to identify cull material. Smaller chipping headrigs and more efficient small-log processing plants have succeeded in reducing the size of the minimum merchantable log in many situations. Finger-jointing and end-and-edge gluing have become relatively common practices, facilitating use of small pieces and nonstandard widths. Still in a development and trial stage are mills specifically designed to utilize cull logs. Roundwood product manufacturers are less reluctant than they have been in the past to make use of dead timber. Some have discovered distinct advantages in dead material for their particular application.

Extended utilization is especially sensitive to market conditions. During depressed market periods, products and processes nearest the manufacturing margin are the first to be discontinued. Given the long-term upward trend in demand for all wood products, however, it seems inevitable that more intensive utilization for conventional products will increase. Much of the material currently considered residue will become an economically available resource for these products.

Forest residues also include a large volume of material suitable primarily for chip, particle, or fiber-based products. Major foreseeable uses for such material are likely to be for pulp, particleboard or fiberboard, or fuel.

In the Northern Rocky Mountain area, there appears to be a relatively close balance between chippable mill wastes and pulpwood demand, with little room for expansion. As demand for pulp chips increases, and competing uses appear, the price of mill-waste chips can be expected to increase. In addition, as greater conversion efficiencies are achieved in plywood and lumber manufacture, available chip supplies may actually decline. When the cost of mill-waste chips approaches the cost of handling and chipping forest residues, the forest residues will become an economically viable source of pulpwood (fig. 5).

Figure 5.--Forest residues include large volumes of material suitable primarily for chip or fiber products, such as paper.

The development of a new class of particleboard products, referred to as structural particleboards, may offer more immediate promise for utilizing forest residues. Structural particleboards are designed to provide the strength and weather resistance necessary for exterior and structural applications such as wall and roof sheathing. To obtain the added strength, the boards are manufactured from relatively long, thin flakes of uniform size and shape. The flakes or particles may be alined in one direction, cross-banded, or combined with veneer face plies. With the exception of large residues such as veneer cores, mill residues are not suitable for the production of acceptable particles. Roundwood or forest residues will be required.

Structural particleboards are in the developmental stage, but their success and rate of market growth are difficult to predict. Historically, the construction industry has been slow to adopt new concepts and projects. If it can compete with plywood, structural particleboard could utilize significant volumes of forest residues within a few years. Assuming that pricing will be comparable to that for exterior plywood, the particleboard industry should find forest residues within economic reach.

Recent concerns about soaring energy costs and shortages of fossil fuels have directed renewed interest toward wood as an industrial fuel. Many industrial firms are facing potential restrictions on the availability of fuels and electrical energy, and at best are operating with interruptible energy sources. One obvious solution is to reconsider the role of wood residues as fuel.

Wood wastes have long been used as fuel by the wood products industry, however, and recent trends within the industry are toward expanding capability to use wood fuel. Residues burned in manufacturing plants can produce both process steam and electricity, with much of the energy used in the form of steam and heated air. Recent developments in wood combustion technology have dramatically improved the efficiency of wood-fired furnaces. Increasing alternative energy costs, physical unavailability of other fuels, and the need to develop self-sufficiency will all contribute toward making forest residues an economically available industrial fuel.

Program studies have included the investigation of product potential represented by residues; processing characteristics affecting drying, treating, chipping, gluing, and other manufacturing treatments; the physical characteristics of products produced from residues; and the economic availability and probable cost of residues delivered to processing facilities. Specific research results are discussed in detail in subsequent sections of this publication. Representatives from wood products firms also discuss the practical considerations that influence the utilization of low-quality wood.

REPORTING THE RESULTS

The purpose of this publication is threefold:

- --To report the results of research conducted by the Residues R&D Program in harvesting and utilization opportunities for forest residues;

- --To provide a record of proceedings of the 3-day symposium exploring both research and industrial experience in residues utilization;

- --To provide a compendium of information useful to those involved or interested in improving the recovery and utilization of forest residues.

Improved resource utilization depends upon better resource information, improved harvesting alternatives, identified product and market opportunities, and knowledge of the economic and management consequences. The information presented in the remainder of this publication covers all of these subjects to some degree. The material is organized in four sections entitled "The Resource," "Harvesting Opportunities," "Utilization Opportunities," and "Economic and Management Considerations." The results and information presented in any particular paper, however, may include aspects ranging all the way from resource considerations to economic implications.

More efficient utilization of our wood resource can substantially extend the available wood fiber resource, providing a base for industrial expansion and economic growth. It is the most effective way to add to timber supply in the short run. Improved utilization practices can also contribute to resolving some of the more difficult environmental and management problems associated with timber harvesting. It is toward these goals that the research program and the symposium have been directed.

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UNIVERSITY RESEARCH IN RENEWABLE RESOURCES: A COMING OF AGE?

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ABSTRACT

The universities, especially those with forestry schools, have been active in residue research for the last two decades. This interest has intensified in recent years as we have firmly recognized the vital importance of reducing waste and stretching our raw material resources. This interest ranges from the ecomomics of residue recovery to the viability of biomass for chemical feedstock. To tap the university's interest and talent, support from the federal government and especially industry will be needed more than ever before to keep our universities the "creators of the future."

KEYWORDS: residue utilization, research, funding

Some time ago, I was asked to address the role university research plays in the resolution of problems in harvesting and utilizing forest residues. Upon reflection, I took it upon myself to broaden that topic to present to this symposium a more general picture of university research in renewable resources. Specifically, I thought it would be informative to say a few words on (a) how universities look at research, (b) how that research is done, (c) where the funds come from, (d) what are some of the issues facing the academic community in research, and (e) where we might be headed as the enrollments begin to stabilize and perhaps even decline over the 1980's. Each of these factors, of course, will have an impact on research in general, including that done on various aspects of residue recovery and utilization.

How do the universities look at research?

A traditional image held by the public over the last two centuries is best described by the English mathematician and philosopher Alfred North Whitehead. "The task of a university is the creation of the future," he wrote in one of his

many essays encompassing a wide range of fields. This statement, albeit brief, sets a high but realistic goal for our institutions of higher education. To me, it refers to the three basic service functions of the universities--teaching, research, and extension.

The research function, in its broad sense, includes not only the type of studies where data are collected and analyzed, but also all other types of creative activities, such as those in the fields of sculpture or music. The research interest of the universities--particularly the older and more established institutions--is strong and very basic. Research is indeed considered a primary function in such institutions, especially in the land-grant universities. You recall the Morrill Act of 1862, the Hatch Act of 1887, the second Morrill Act of 1890, and the Smith-Lever Act of 1914, framing the land-grant concept establishing research as a prime function of the universities. Both basic and applied research have traditionally been carried out by university professors who undoubtedly wrote the definition of research in the Webster's Third New International Dictionary:

> . . . critical and exhaustive investigation or experimentation having for its aim the discovery of new facts and their correct interrelationships, the revision of accepted conclusions, theories or laws in the light of newly discovered facts, or the practical application of such new or revised conclusions, theories, or laws. . . .

In fact, this definition is utilized in policy statements of many universities as applied to the research function of those institutions. Note that both basic and applied research are encompassed within the definition. Many universities now aspire to ". . . imbue the human mind with knowledge, tolerance, and vision and stimulate a lasting attitude of inquiry." Furthermore, the mission of the universities is to serve the people as a center of learning for the advancement, preservation, dissemination, and use of knowledge. The advancement of knowledge obviously requires involvement in research.

FORESTRY RELATED RESEARCH

Forestry research has a long history in our universities. Early research on using native and exotic trees for windbreaks and various aspects of wood utilization, among others, goes back to the early decades of this century. The research was of necessity low key; it occupied that portion of the professor's time which was not needed for teaching. With the exception of some surge occurring after World War II, slow but gradual increase in research took place over the half-century from about 1910 to around 1960. Then in 1962, a significant event occurred: the enactment of the McIntire-Stennis Act which authorized federal funds for research at universities. This act, coupled with several other developments, brought about a quickening pace in forestry and utilization research. These developments included a phenomenal growth in student enrollments, including graduate programs, over the decade following the Act; the prospect of increased reliance on forest resources in meeting our material and recreational demands; an increased environmental awareness and the attendant need for better information; and finally general increases in federal research and development dollars.

The McIntire-Stennis Act was a major landmark legislation. This was the first time that the Congress of the United States recognized the role that the forestry schools can play in research and encouraged that role by authorizing federal dollars on a regular basis. The Act, appropriately, recognizes both research and training aspects of the program. Today, some 62 institutions, both land grant and

non-land grant, participate in some 500 totally or partially funded projects. Many of these projects deal with various aspects of forest residue recovery and use. Nationally, some 600 scientists and about as many students participate in the program. The total budget for the program is about $9.5 million, with institutions receiving funds ranging from small sums to several hundred thousand dollars. The funds are allocated on a formula basis to each state, taking into consideration the timber harvest, the forest land base and non-federal dollars available for research. A significant advantage derives from the regularity of these dollars, which permits some degree of planning in addressing research problems.

Many of you are well aware of the phenomenal enrollment growth occurring in the forestry schools over the last 15 years. Departments handling a few dozen students suddenly found themselves faced with burgeoning enrollments; in some cases, student numbers quadrupled. Supply of these graduates, however, clearly exceeded demand. Many graduates, failing to find the desired job, found entering graduate school a viable option. The result: enrollment growth in graduate programs, providing a good source of research workers.

This audience needs no elaboration on the increasing importance this country and indeed the world is placing on forest resources. These resources are being "rediscovered" and sometimes referred to as the "renewable quads" in an energy hungry society. Greater demands on these resources, however, must be coupled with greater sophistication in the way we deal with them. Judicious use of existing information as well as new knowledge being developed through research will be necessary to enable us to produce and recover more per acre. This symposium is an example of people presenting information so that we may be able to recover economically the large quantities of available residue.

In a recent meeting in Lewiston, Idaho, I noted the statement made that the residue from the Clearwater National Forest alone can supply the fuel for two 25-megawatt power plants for many years to come. How about competing demands for more pulp and board production and other forest products? How about the impact of such residue recovery on site impaction, on nutrient cycling? Answers to these questions are not easily obtainable in every location and require careful research and analysis.

We have come to a stage in our societal development when the public demands reasonable environmental care in extracting more material and services from our forest acreage. This sort of demand will continue over the decades ahead. It will continue to guide our research along a course which will yield greater rewards: not just how to get more on less land, but how to do it harmoniously with nature, protecting the land base for optimum production in the years ahead.

HOW IS RESEARCH DONE AT UNIVERSITIES?

Doing research is not unlike cooking a good meal. Thoughts must go into it as to what is to be served and how it is to be prepared. Then logistics and ingredients must be combined and the results served in a palatable manner so that it looks good and tastes and digests well. Should any of the major elements in logistics or ingredients be missing, then the quality suffers and the results are not as appealing.

The universities do have trained manpower willing and eager to participate in research. Support dollars, however, are not always available. Participation in research is indeed expected of the university faculty, as the basic philosophy of "publish or perish" prevails on most campuses to varying degrees. A variety of scenarios occur in doing research at our universities.

The Brave Professor Scenario

Here is a situation when the professor is fully committed to teaching but still manages to "steal" some time from his office or family to engage in a "pet" project. The Brave Professor scenario is characterized by virtually no formalized budgeting and indeed no budgets. The department head might even jump on him if he makes "too many" long distance calls or uses the copying machine "excessively." This research often involves a different interpretation of published material, or taking "another look" at something already known. For the productive person who aspires to research, this scenario will soon become frustrating. Aggravation is compounded when he finds that promotions, merit raises, and the like are still significantly influenced by publications, books, etc. He continually argues for more time and money to do research, with little result. He is good at talking because that is what he does all day long in his many classes. At times he feels like a tape recorder, since he has been assigned several sections of the same course and repeats the same lecture time and time again.

The Low Budget Scenario

The low budget professor has been allotted some of his time (perhaps 20-40 percent) to research and has managed to secure a small budget (several thousand dollars) from the limited university funds to work on a project. He is not sure how many years the budget will be maintained; thus, if he is wise, he periodically informs his administrators of the payoff from the project. From the small budget, he is able to hire a student or two at minimum hourly wages (or through the federal Work-Study program) to collect data, do library search, man a monitoring device and the like. He might even manage to pay for a little computer time. He and his administrators know the budget is less than what he really needs, but the work goes on at a level of productivity below what the professor is capable of delivering.

The Pay-it-Yourself Scenario

In this scenario, the professor is serving as the major advisor to one or two graduate students. The student was accepted on the proviso that he provide his own financial support. This is fine until it comes to meeting the research requirements for the degree. Then, the challenge sets in when he must select a research topic that is (a) acceptable to the major advisor and the advisory committee, (b) timely, (c) feasible, and (d) doesn't cost money! The challenge confronts both the student and the professor. There are those in the academic community who argue that it is indeed unwise to admit a student to graduate studies when funds are not available to facilitate a reasonably good research environment. The argument continues that it is simply too expensive to do research and very few students have the financial resources to meet their research requirement. Under these circumstances, the professor and the student still manage to come up with a low-budget project for the student which often does not result in any publications.

The T.A. Scenario

Many departments, especially those with heavy teaching commitments, are often provided with one or more teaching assistants (TA's). The TA is given a stipend which covers his basic food/shelter expenses. If the major professor can manage the support costs through a small grant, this team is able to work on a project with reasonable success. This is especially true if the support funds can provide wages for one or more undergraduates who can be assigned to various routine tasks, i.e., data collection, lab maintenance, and the like. The TA is still limited as to the amount of time he can devote to the research as he has some basic and at times heavy responsibility in teaching.

The More-Like-It Scenario

In this scenario, the professor supervises one or more funded graduate research assistants and has control over adequate support dollars. Good field data followed by careful analysis can be produced under this arrangement. Travel and publication dollars permit participation in professional meetings and symposia, and journal articles permit dissemination of the results. Copies of more detailed reports can also be made and submitted to those agencies likely to benefit from the findings. Traditionally, this scenario has proven to be successful in carrying out research at universities.

The Master Grantsman Scenario

This scenario often involves a well-known professor who either happens to be in a highly fundable area and/or is a master grantsman. He is able to secure resources, sometimes well in excess of $100,000 per year, with which he hires one or two research associates, a technician, and has basic responsibility for some four to ten graduate research assistants. He is officially involved in some two to six major projects and has had to delegate responsibility to his associates. He, himself, has turned into what is sometimes referred to as the "bio-politician" with a strong scientific background. Several publications per year bear his name. He travels extensively, consulting, lecturing, and continuously looking for new sources of funds. The scenario can become very productive, generating high quality research information with good potential tie-in with the users of that information.

The Multi-Disciplinary Scenario

In this case, the overall project involves a broader array of scientists encompassing a variety of fields. The project is divided into manageable subprojects which are, in turn, handled by a professor and his support staff (research associates, technicians, students). An overall coordinator or director "brings it all together" and prepares the overall report. This scenario requires special skills and experiences in working with a variety of people and disciplines, but has the reward of making sizable contributions to the problem area. The universities are now attempting to strengthen their interdisciplinary efforts in research, as there is a general belief that such teams not only can be put together readily in a university, but they can strengthen the university's research posture by involving a significant section of faculty and students.

The Cooperative Scenario

In my experience, one of the most exciting scenarios involves cooperation among several agencies and organizations in teaming up with university researchers in a continuing researcher-user partnership. In this scenario, the overall effort is subdivided in a similar fashion as that pointed out for the multi-disciplinary scenario, with some of the team members employed by outside research agencies such as the Forest Service and the industry. This partnership gives a real-world touch to the program and has the reward of seeing the information used soon after it becomes available. The industry, the government, and the universities can be natural partners in the field of forestry and wood utilization, providing both the financial and manpower needs for projects. The cooperative scenario is now taking shape in the fields of tree improvement and forest fertilization in several parts of the United States. In these situations, the universities often produce a portion of the research information and also serve as an integrative means of receiving information from all cooperators and analyzing it so that it will be useful to the users.

FUNDING RESEARCH

Doing research costs money--and plenty of it! But if it is done right, the returns are substantial. Where do the universities get the funds to carry out their research function?

Briefly, state and federal governments provide a major portion of the needed dollars in their regular budgetary process. The state portion largely provided the dollars allocated to the faculty salaries. If Professor Brown's job description indicates, for example, 50 percent research, and if Professor Brown is entirely paid from state dollars, then those dollars are, in reality, being provided by the state for research purposes. Many do not realize that the state governments are in this manner underwriting a substantial amount of dollars for research at our universities. Also, many institutions are budgeted by the state for additional funds for temporary salaries and operating expenses. For example, to meet matching requirements for the Hatch and McIntire-Stennis Act funds, the states often need to allocate dollars for research in addition to the salary dollars. This brings me to the federal funds which are budgeted on a regular basis for research at our universities.

The Hatch Act and the McIntire-Stennis Act provide a regular source of funds for forestry-related research as indicated earlier. As you know, the Hatch Act funds have provided the financial backbone for agricultural research at our land grant universities. Other budgeted federal funds in mining and in energy are now gradually becoming available.

Gifts and scholarships are an additional source of funds. Most gifts and scholarships have certain restrictions as to how and in which areas they are to be spent but some provide student stipends and operating dollars for research.

In recent years contracts and grants have provided a major share of funding for university research. In some forestry schools, these sources of funds could be as high as 50 percent or more of the total research dollars available to the

school. These funds are generally soft, with possible substantial variations in amounts received from year to year. Many such grants and contracts are competitive, requiring special skills, time to develop proposals, and finesse in grantsmanship by the faculty and administrators. Since the universities are becoming increasingly dependent on such funds, they are an element keeping many in our universities "on their toes." Where do such funds go? To staff, salaries, materials, travel, graduate assistantships, computer time, publications, and the like. Where do such funds come from? By far, the federal agencies are the source of most such funds. My experience in research administration indicates that over 90 percent of such funds are federal funds either directly originating from the particular agency headquarters in Washington or more often filtering through other federal or state organizations. In the renewable resources areas, industry provides a very small percentage (perhaps 2-5 percent) of research dollars to the universities in the western United States.

To respond to the increasing demand for research, many of our forestry schools have hired staff on such soft funds, and some have moved ahead in placing a portion of the salary of their regular staff also on such dollars. It is now common to see faculty in our forestry schools on 9-month appointments, with the responsibility of securing salaries for the 3-month summer period falling on the individual professor. Indeed, some faculty members may also have to secure a portion of their regular 9-month salary by writing research proposals and attempting to secure grant funds for the proposal. This process, although lessening job security, has contributed significantly to an expanded research program by the universities.

CURRENT ISSUES FACING UNIVERSITIES

It is now being predicted that the universities will encounter enrollment drops in the 1980's. The Census Bureau estimates that the number of 18-year olds in the United States will drop by more than 18 percent between now and 1990. This is expected to result in smaller faculties as fewer students will enter universities. Will it also imply a smaller research role for the universities? Will it affect the quality and the vigor of research as the younger Ph.Ds are less able to secure university faculty positions? Will it discourage our talented undergraduate students from entering graduate schools as the job market outside the universities improves and the prospect of securing faculty positions decline?

No one has a firm answer to these questions. A recent Harvard study generally paints an optimistic picture as regards research in our universities. The study, authored by Professor Robert E. Klitgaard, an associate professor in the John F. Kennedy School of Government, concludes that the decline in output of university research jobs will be much smaller than decline in university teaching jobs. He claims that the aging faculty will not be less productive than the young Ph.Ds. A study by Professor Stephen Cole at State University of New York at Stony Brook found that "scientists are slightly more productive during their forties" and that "in most of the fields studied, the scientists over the age of 60 were not much less productive than those under 35." Thus, Mr. Cole writes, "It is unlikely that an increase in the mean age of our scientists will, and of itself, bring about a meaningful decline in our scientific capacity." Some of us in higher education even advance the possibility that the quality of overall research may increase as the less serious researchers drop out of the picture, shifting dollars to stronger and more committed scientists. This is a possibility that Klitgaard also advances. How about promising undergraduate students bypassing graduate schools? This is indeed a realistic possibility.

To keep research in our universities vigorous, increasing funds from all sources, particularly the federal government and the industry, will be needed. It is time that the forest products industries recognized the substantial talent which exists in our universities and find the means of tapping that research talent. Indeed, industry/university partnership is a significant challenge which has the potential of combining the substantial financial resources of the industry with the highly trained manpower at our universities in addressing such issues as forest residue use, intensive forest management, integrated pest management, energy, even new product development. These are substantial challenges requiring sizable resources and talent. It is indeed a national challenge to facilitate this industry/university partnership. Currently, the Carter Administration is in the process of taking several steps to encourage technological innovation. One of these involves increased support for university-industry cooperative research and development programs. The federal government also proposes the creation of university-based technology-research centers and adoption of a liberal, government-wide patent policy which would give the inventors exclusive licenses to commercialize their inventions resulting from federally sponsored research.

The universities are ready to cooperate in maintaining and improving the technological backbone of the forest products industry. The question involves whether the industry has recognized the opportunity and seizes it to benefit itself and the society as a whole.

THE RESOURCE

Only during the past few years have forest residues been elevated to the status of a "resource." In fact, the term "residue" is relatively new; historically, the tops, small trees, and cull and dead material remaining after logging were termed "brush" or "slash," strictly a disposal problem. The sheer volume of wood contained in residue material commands attention, however, and current emphasis upon improving wood utilization focuses upon the product potential of the residue resource.

National projections predict continuing increases in the demand for wood and fiber-based products. In the face of a declining land base available for timber production, concerns about environmental impacts, and constraints in harvesting activities, better use must be made of the available resource. In the short run, more complete recovery and use of the total available wood resource is the most effective way to add to supply.

Interest in residue utilization raises some significant questions about the character and potential of the resource:

--How much residue material is there in our forests, and how does measurement of this material fit into the broader framework of resource inventory?

--What are the characteristics of this material in terms of volumes per acre, quality, size, and variation from one forest type to another?

--What are the costs of harvesting this material?

The information presented in this section addresses these three perspectives on forest residues as a viable wood resource.

RESOURCES EVALUATION AND RESIDUE: WHERE WE'VE BEEN AND WHERE WE'RE GOING

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ABSTRACT

In the past, analyses conducted by regional Resources Evaluation (Forest Survey) Units have considered forest residues only in passing. Recent political and economic developments have caused more attention to be focused on forest residues both for conversion to forest products and as a source of energy. This will undoubtedly lead to improved methods of assessing the forest residue situation and improving its utilization potential.

KEYWORDS: forest inventory, utilization, residues

In this paper, I would like to briefly outline how Resources Evaluation has treated forest residue in the past, what changes have been made recently to more adequately address the forest residue issue, and finally to consider what changes will have to be made in the future to provide basic input into a forest residue decision model.

Before we can evaluate the residue situation in the Rocky Mountains we must first define what we mean by residue. In the dictionary, residue is defined as "something that remains after a part is taken, separated, or designated." The brochure announcing this Symposium stated that forest residues include small trees, cull and broken logs, tops and dead trees with the latter being the largest single component. Resources Evaluation, however, is much more restrictive in its definition of residue.

First, the only trees that can be considered are live trees of commercial species except those that are cull because of form, rot or other defect. Second, only the portion of these trees, between a one foot stump and a four inch top, left in the woods after or killed during a logging operation is considered to be residue. Slash, that is, tops and limbs, cull trees, dead trees, etc., are not included in our estimates of logging residue. Nor do we include any material on lands classed as unproductive. It is, therefore, obvious that our estimates of residue or--more precisely--logging residue are conservative.

This is not to say that small trees, cull trees and dead trees are not taken into account. Quite the contrary, every effort is made to sample for this material. It is just that these items are displayed elsewhere and are not included in our estimates of residue or removals.

Estimates of logging residue are obtained through the use of various factors developed from utilization studies. These studies, conducted at approximately five year intervals, are designed to provide information about the source of material that is converted to various industrial products. Once an active logging operation for a particular product, such as sawlogs, has been selected, a crew will visit the site to take a series of standing tree measurements. These measurements reflect National or regional merchantability standards and include such items as stump diameter, d.b.h., height to a fixed top and total height. Additionally, the species and product are also indicated. After the tree is felled, a second set of measurements is taken to reflect the degree to which the tree was utilized. These include stump height, and diameter, log length and diameter at small end, length of material from small end of log to a fixed top diameter, if left behind, and those sections between a one foot stump and the fixed top that are bucked out because of breakage or rot.

Also measured is the amount of material falling outside the merchantable limits that will be converted to industrial products, including material from cull trees and other nongrowing stock sources.

These measurements are then converted to ratios or factors to predict the utilization or lack of it by product and species. These ratios provide the adjustments necessary to convert total industrial harvest to an estimate of annual removals.

To illustrate this process, consider first the case of overutilization. Assume that we have determined that 1,000,000 board feet of sawlogs have been delivered to a sawmill and we need to relate this to our standing inventory. From our utilization study, we find that on the average, sawlog harvesting operations left 6-inch as opposed to one foot stumps, went to a 7-inch as opposed to 9-inch top, utilized major limbs and obtained some logs from cull material. Our estimate of sawtimber removals then would be 1,000,000 board feet gross removals minus the stump volume, minus the additional volume above the 9-inch top, minus the volume in the major limbs utilized, minus the volume of cull material utilized. If all of the deductions amounted to ten percent, then for every one million board feet of reported harvest, we would only show a 900 thousand board foot reduction in inventory. In this example, there would not be any residue material.

On the other hand, if the loggers are leaving three foot stumps, stopping at a 12-inch top and not utilizing any other material, the inventory adjustment would be in the other direction. That is, if this underutilization amounted to 10 percent, then every one million board feet of reported harvest would take 1,100,000 board feet of inventory. The additional 100,000 board feet of material would be reported as logging residue, and the reduction in inventory would be reported as 110 percent of sawtimber volume removed.

Recent estimates of harvest for the Rocky Mountains may put these factors into proper perspective. In 1976, 95 percent of the roundwood material converted into industrial products came from growing stock trees, more than 4 percent came from salvable dead trees, and the remainder--less than one half of one percent--was evenly divided between cull tree and nongrowing stock sources.

In terms of total removals, some 88 percent went for conversion into industrial and domestic products, nearly eleven percent was left in the woods as logging residue. The remainder went into "other removals." "Other removals" represents the volume of material removed in cultural operations--timber stand improvement, precommercial thinning, and other nonproduct harvesting operations--land clearing for agriculture, roads, lakes, etc., and the volume of material left standing on forest land that has been set aside or otherwise withdrawn from the timber growing base but still supports standing trees. The volume in this category will be discussed later.

Before going into needs for the future, we would like to briefly discuss our treatment of mortality, cull, and small trees. Mortality and cull trees are selected for tally using the same sampling rule that is applied to all live trees. A prism with a basal area factor of 40 is used to determine whether or not a tree qualifies for selection. Once selected for measurement, it is usually obvious whether the tree is alive or dead. Up until recently, however, a dead tree was classified as mortality and/or salvable dead, and a tree class, i.e., growing stock or cull, at time of death was assigned. No attempt was made to further describe this material.

Recent developments in the forest products industry, namely advancing technology in pulp conversion and the house log industry, have made certain dead trees, both standing and down, economically feasible for conversion into products. As a result, our definitions and classifications of mortality have been broadened. For example, we currently record the amount and kind of defect on salvable dead material, and we indicate whether the tree is standing or down. In the case of a large windthrow, the inventory crew will actually attempt to "resurrect" each tree to determine whether or not it would have qualified for tally. We are also recording nonsalvable dead trees, both standing and down.

A live tree is considered to be cull if one or more of the following criteria are met:

1. Live sawtimber tree having more than two-thirds of its gross board foot volume in cull material including rot, crook, sweep and other defects such as excess limbiness or open grown (wolf tree).

2. Sound live sawtimber trees that do not contain at least one twelve foot log now or prospectively.

3. Live poletimber tree with more than two-thirds of its gross cubic foot volume in cull material including multiple stems, excessive crook or a butt section with less than 8 feet of usable wood.

4. Sound live poletimber trees that are excessively limby or open grown (wolf trees).

5. Seedlings and saplings which are unlikely to grow into growing stock because disease, crook, animal damage, or supporession.

And finally,

6. Off-site species.

Cull trees are further classified as rough or rotten depending on the amount of rot, serious fire or basal scars, and dead bole sections. If these defects account for more than one-third of the volume lost in a cull tree then the tree is coded as a rotten cull.

Small trees; that is, trees from 1.0-4.9-inch d.b.h., are tallied using a 1/300 acre fixed radius plot on every point of our 10-point cluster. These small trees are measured in essentially the same manner as their 5.0+ inch d.b.h., counterparts, and are included where appropriate in our computation procedures. Until recently, however, there were no volume estimates computed for this segment of the inventory.

It should be quite apparent from the above, that in the past Resources Evaluation was primarily timber oriented. The McSweeney-McNary Act of 1928, our enabling legislation, authorized the Secretary of Agriculture to make and keep current a comprehensive survey of the present and prospective requirements for timber and other forest products in the United States, and of timber supplies including a determination of the present and potential productivity of the Nation's forest lands. Thus, our primary objective was to relate everything to that component of the forest that could produce industrial timber products. We only took detail tree and area data on commercial timberland, that, by definition, was land that could produce a crop of industrial wood at an annual rate above 20 cubic feet per acre per year at culmination of mean annual increment. Our tree measurements were confined to growing stock trees that, by definition, were those trees that would be featured in management. Our measurements were confined to that portion of the tree that had the highest probability of yielding an industrial product. In other words, we were what some refer to as timber beasts and we were pretty good at it.

In August of 1974, however, the Congress passed and the President signed the Forest and Rangeland Renewable Resources Planning Act (RPA). The Act amended our enabling legislation to the extent that timber is no longer the driving force behind Resources Evaluation activities. Timber hasn't completely taken a backseat, it is just sharing the driver's seat with the other renewable resources such as wildlife, rangeland, water, and so forth. As a consequence, we have had to change our way of thinking and one area receiving considerable attention lately is forest residues. Current economic conditions have also added impetus to the desire to know more about the residue situation.

How will this shift in program direction affect how we evaluate forest resources in general and forest residues in particular? First, we will have to rethink our concept of forest residue. That "cull" tree standing in the middle of the forest may be home for some rare woodpecker; that slash left on the forest floor may be what will determine the survival of the seedling that will be planted there five years hence; and that pile of wind thrown lodgepole may be the security blanket for various and sundry critters that we don't see. If this is the case, then perhaps what we consider to be forest residue may not be residue at all. Second, to make these kinds of determinations will require a better or more detailed information base which in turn will require improvements in our current inventory procedures and the development of new methodology.

Predicting total woody biomass is one of the more important gaps yet to be filled. This problem is not unique to the Rocky Mountains. In fact, in 1977 a National level task force was appointed by then Forest Service Chief McGuire to develop a process for determining the amount of woody fiber that might be available for conversion to products or used as an alternative energy source. As a result of the recommenda-

tions of the task force, a study team was commissioned to draw together information currently available in the field of biomass prediction and to develop a National biomass handbook. The final product should consist of a series of equations and/or tables and should be available in the very near future.

Once these results become available we may have to modify how we sample the forest resource. For example, stem diameter at the base of the crown is one parameter used to predict total crown volume--a measurement we are not taking at the present time.

To more adequately assess what is happening to the standing inventory we will have to conduct more frequent and comprehensive utilization studies. Our measurements will have to be somewhat more flexible and will certainly have to be more detailed. For example, we will have to have the capability to shift from one merchantability standard to another. We will also have to develop the ability to predict or assess the slash situation for various types of logging operations. This is one area that has long been of concern to those who are interested in the energy potential from harvesting operations, and our current estimates of logging residues do not adequately address this problem.

The whole area of "other removals" will require additional study. As a minimum we will have to separate that portion of "other removals" that is still standing from the component that is actually severed. At present some of the volume that is on lands that have been administratively designated as a park or wilderness is being included as cut material that is potential biomass for energy conversion, when in fact the stands on these lands are probably no different from those which occur on adjacent lands. By providing estimates of the forest resource on reserved lands we can accomplish two objectives.

First, the fiber base will be more adequately described and, second, the potential from these lands can be assessed. This could become quite important in view of recent international energy developments.

Timely remeasurement surveys that include detailed measurements on all forest lands would also increase our ability to deal with shifting resource concerns. The target cycle for Resources Evaluation is about 10 years. If this cycle could be achieved in the Intermountain Region, we would be able to determine more accurately when a tree died, for example. We would also have time series information which could be used to model the dynamics of forest stands on an extensive basis.

One area that deserves serious consideration is the refinement of our inventory process to indicate how much residue is currently in the woods and to predict where large volumes of residue may occur in the future. We also need the measurements of certain descriptive parameters that will indicate the proximity of these stands to developed markets. In other words, the manner in which a manager treats a stand with high mortality potential could very well be tempered by the stands nearness to an all-weather road, the steepness of the slope on which it falls and its elevation. Thus, at a minimum, these parameters should measure the degree of physical accessibility.

Partner to determining accessibility is determination of the availability of the present or potential residue resource. This will require research outside the normal inventory process. Generally speaking, residues are available anywhere they occur on public lands that have not been withdrawn from timber production. The private sector, on the other hand, presents a completely different set of issues. Residues on these lands may be physically accessible, but because of owner attitudes they may not be available to the market. This issue has also been receiving considerable attention at the National level in recent months.

In conclusion, changing our approach to inventory should provide better estimates of the total forest resource situation including forest residue. We must keep in mind, however, that inventories conducted by Resources Evaluation are extensive in nature and, in the West, usually cover only the state and private lands. These inventories can only provide sample derived estimates of the amounts of various forest resources by some categories that may reflect their utility for conversion to various wood products, but we cannot tell you where the resources are. Therefore, any thoughts of being able to capture and use the salvable material within a given geographical location has to be tempered with economic considerations. Moreover, future analyses of our forests and the outputs they produce will have to consider both timber and nontimber values for the residue resource as well as the growing stock inventory.

RESIDUE CHARACTERISTICS IN THE NORTHERN ROCKY MOUNTAINS

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ABSTRACT

In the northern Rocky Mountains, 350-450 million cubic feet (9.9 to 12.7 million m^3) of logging residue is generated each year. This residue consists of dead standing and down trees, green unmerchantable trees, broken pieces and the tops and branches of those trees removed in logging. Up to 60 percent of the residue material is technologically suitable for wood products, but condition, size and product potential vary among forest types. Other factors which influence residue utilization are level of harvest, trends in wood processing, industrial uses and economic conditions.

KEYWORDS: forest residue, logging residue, utilization

INTRODUCTION

During the past 5 years, the Forest Residues Utilization research unit has made an extensive study of forest and logging residues in the principal forest types of Montana, Idaho and Wyoming. The purposes of this study were to develop wood biomass data as a baseline for evaluating impacts of alternative residue treatments and to estimate the utilization potential of forest residues. Over 3,000 samples were taken at various research sites and in undisturbed stands in National Forests throughout the area.

Residues were measured using standard fixed or variable plot techniques for standing trees and the planar intercept (line transect) method for down material (Brown 1974). Characteristics such as piece size and condition were determined by measurement or estimation. The principal forest types included in these studies were lodgepole, larch, grand fir, spruce-alpine fir and Douglas-fir. Most timber harvest and residue management problems occur in mature and overmature forests of these types.

This paper summarizes residue characteristics that affect harvest and utilization potentials. The characteristics of woody material were reported earlier (Benson and Schlieter 1980a).

CHARACTERISTICS OF FOREST RESIDUES

Old-growth conifer forests typically contain a sizable volume of material--such as dead, cull, rotten and undersize stems--not normally suited for sawlogs or veneer logs. Because disease, insects, bad weather and fire suppression occur neither regularly nor evenly throughout stands, the amount and condition of residues vary widely. One stand, because of reasonably good spacing, may have escaped serious disease or insect problems and have very little residue. The trees in another stand in the same forest type may have experienced extensive crowding and fire suppression that produced many small defective stems; similarly, stands that have suffered heavy rot or insect mortality may have more residue than merchantable material. The data that follow should be interpreted as averages for each type.

Volume and Condition

When considering utilization of residue material, the volume per acre and the condition of residues are of key importance. Furthermore, even if no utilization is planned, the physical presence of residues affects the costs both of logging and of subsequent activities such as fuel management and regeneration.

The volume of all wood 3 inches diameter (7.6 cm) and larger on our study sites is shown in table 1. Forest inventory and sale cruise data normally present smaller volumes because they tend not to include all the types of material reported here.

Table 1.--Volume of wood in mature stands, in residue study areas, by component.[1]

	FOREST TYPE					
	Lodgepole	Larch	Douglas-fir Moist site	Douglas-fir Dry site	Grand fir	Spruce-Alpine fir[2]
	ft³/acre					
Green Trees						
Merchantable log	2225	3401	2546	1658	4283	2000
Cull	119	222	334	52	564	391
Top	457	132	105	75	208	300
Small stems	244	663	527	300	156	380
Sub total	3045	4418	3512	2085	5211	3071
(m^3/ha)	(213)	(309)	(246)	(146)	(364)	(215)
Standing Dead						
No defect	436	86	180	0	24	153
Sound defect[3]	291	30	49	78		
Solid rot	139	493	36	22	256	68
Crumbly rot	0	302	55	0		
Sub total	866	911	320	100	280	221
(m^3/ha)	(61)	(64)	(22)	(7)	(20)	(15)
Down						
No defect	356	108	267	43	281	455
Sound defect[3]	310	66	52	19	7	43
Solid rot[4]	213	124	137	181	309	106
Crumbly rot[4]	233	1196	398	527	1903	262
Sub total	1112	1494	854	770	2500	866
(m^3/ha)	(78)	(104)	(60)	(54)	(175)	(61)
TOTAL, ft³/a	5023	6823	4686	2955	7991	4158
(m^3/ha)	(351)	(477)	(328)	(207)	(559)	(291)

[1]Top volumes and stem volumes for small trees were compiled from recently published formulae based on species, d.b.h., and height (Faurot 1977).

[2]Breakdown of totals into component is estimated.

[3]Sound defect includes crook, sweep, fork, splits and drying checks that prevent use for solid wood products but not for fibers.

[4]Solid rot includes pieces with rot that can be handled in logging; crumbly rot is material that will not hold together in logging.

Total stand volumes ranged from about 3,000 ft^3/a on dry Douglas-fir sites to nearly 8,000 ft^3/a on grand fir sites. In most forest types about half the total volume consisted of green merchantable logs (fig. 1), and the condition of other standing residue material varied. In lodgepole pine and spruce-alpine fir, much of the residue was sound dead material. These forest types occur at high elevations with dry, cool conditions that do not favor rapid decay. On the other hand, in grand fir and western larch (which favor moister, warmer sites) rotten dead material predominated. Cull green material with rot also was substantial in moister forest types.

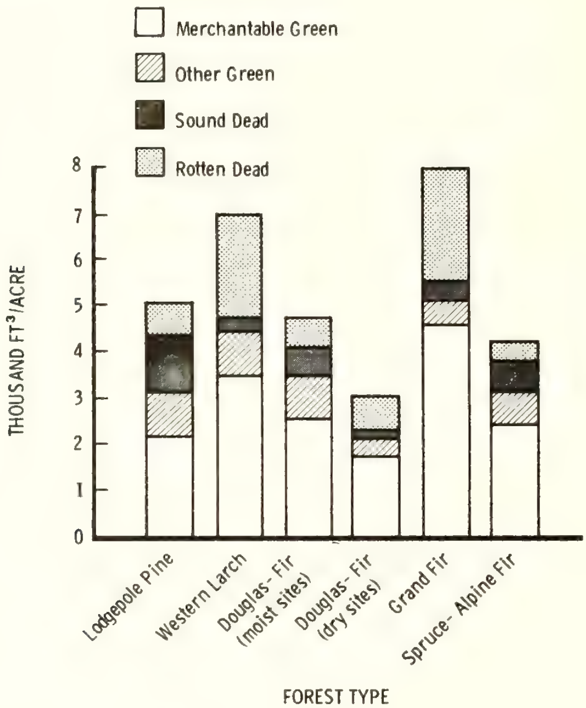

Figure 1.--Volume of wood 3 inches (7.6 cm) and larger in diameter in principal forest types.

The condition of down material appears to be related to decay conditions. In grand fir and larch most of the down material was crumbly rot that could not be removed from the site with conventional logging equipment. In lodgepole and spruce-alpine fir about three-fourths of the material was sound or had only limited defects that would not preclude harvesting (fig. 2).

Figure 2.--Most of the dead and down material in lodgepole stands is suited for product utilization.

Size and Number of Residue Pieces

Because utilization potentials and the costs of harvesting both relate to the number and size of the residue pieces involved, these characteristics were measured in detail for some of our samples.

In lodgepole pine and Douglas-fir sites representing a range of residue conditions, we estimated the following distribution of residue piece sizes:

Condition, diameter, length	Percentage of harvestable residue	
	Lodgepole pine	Douglas-fir
Sound, 6"+, 18'+	43	53
Sound, 6"+, 9' to 18 '	8	9
Sound, 3" to 6", 9'+	29	19
Sound, all diameter, less than 9'	5	9
Solid rot all diameters and lengths	15	10

(Source: Outlook for Utilization of Forest Residues, Northern Rocky Mountain Area, Unpublished Report, USFS Forestry Sciences Laboratory, Missoula)

These estimates indicate that about half the volume of usable residue material was in fairly large pieces or whole trees. Pieces greater than 6 inches in diameter by 18 feet in length averaged 15 ft^3 per piece. In most cases, small green and standing dead trees were intact and of full length; down material was often broken, however, which meant more pieces with smaller volumes. There was also considerable variation among forest types in the number and size of sound, usable, down pieces. Lodgepole pine averaged 127 sound down pieces per acre; western larch 65; and dry Douglas-fir sites 18.

When all sound standing and down material is taken into account, there are potentially 500-800 pieces per acre (1235-1975/ha) in a typical lodgepole pine stand and 200-400 pieces/a (495-990/ha) in Douglas fir (estimates were derived from Benson and Strong 1977; Benson and Keck[1]; Benson and Schlieter 1980a). About 200 stems per acre (495/ha) in lodgepole stands, and 100-150/a (245-370/ha) in Douglas-fir stands, are merchantable green trees. The remainder are residue pieces--300-500 pieces per acre (740-1235/ha) in lodgepole, and 100-250 (245-615/ha) in Douglas-fir.

Product Potential

Potential products were estimated for several forest types. The number of product pieces that could be recovered from each standing or down dead piece was determined, beginning with the product of highest value (table 2). In lodgepole pine over 350 product pieces per acre (865/ha) were recoverable; in Douglas-fir about 70 (170/ha), and in larch about 40 (100/ha).

Specifications for these products vary from one location to another but the size requirements used in the study were typical. Dead material of certain species is not currently used for some of the products listed in table 2. In the larch and Douglas-fir types, for example, only a few pieces are suited for solid wood products, and most have defects that prevent use for anything except pulp wood.

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[1]Benson, Robert E., and Kenneth Keck. 1979. Forest residues on the Targee National Forest. Mimeo. Rept. Forestry Sciences Laboratory, Drawer G, Missoula.

Table 2.--Number of potential products from standing and down dead pieces, selected forest types.

Product and type piece[1]	Lodgepole pine	Western larch	Douglas-fir moist sites
	pieces/acre		
Houselogs			
standing	9 (22)	1 (2)	2 (5)
down	13 (32)		
Sawlogs			
standing	21 (52)	3 (7)	7 (17)
down	20 (49)		
Corral rails			
standing	43 (106)	3 (7)	5 (12)
down	46 (114)		
Posts			
standing	36 (89)	1 (2)	2 (5)
down	44 (109)		
Pulp bolts			
standing	51 (126)	30 (74)	57 (141)
down	75 (185)		

[1]Minimum specifications used were as follow:

Houselogs-- 9 inches diameter, 8 feet long; no crook, sweep, rot, or checks that would preclude use as houselogs;
Sawlogs-- 6 inches diameter, 8 feet long, 1/3 sound;
Corral rails-- 3 inches diameter, 10 feet long; reasonably straight, no rot or major checks;
Posts-- 3 inches diameter, 7 feet long; no crook, rot or major checks;
Pulp bolts-- 3 inches diameter, 8 feet long; sound enough to hold together in yarding.

LOGGING RESIDUES

The amount and characteristics of residue material that actually remains after logging may or may not be closely related to predictions based on pre-harvest conditions. Often residue material becomes broken in the logging operation so the post-harvest potential is reduced.

In one study of 33 cutting units, between 1,800-2,600 ft^3/acre (126-182 m^3/ha) remained in units that received conventional utilization; only about 20 percent of this material was over 9 feet (2.7 m) long. In unlogged stands, however, about 80 percent of the residue material was over 9 feet (2.7 m) long, which indicated much of the residue potential was lost due to breakage in logging. On the other

hand, where removal of all pieces over 9 feet (2.7 m) long was required in utilization specifications, only about 15 percent of the total preharvest volume remained as residues. This suggests that when logging is intended to remove residue material it can be done without excessive breakage.

In our study about half the volume remaining after conventional utilization was green material. With close and intermediate residue utilization levels, virtually all the green material was removed, with only the unsound or broken small pieces of dead material remaining.

In another study, six timber sale units logged to conventional sawlog standards had from 1,800 ft^3/acre to over 3,800 ft^3/acre (126 m^3 to 266 m^3/ha) of residue remaining. Two of these units were relogged to recover pulpwood and any other products that could be made. This resulted in a 44 percent reduction of residues in one area and a 59 percent reduction in the other (Chase 1979).

In typical mature or overmature stands, where about half the total volume is residue material, the proper combination of utilization standards and logging could remove most of this material for utilization (fig. 3). Based on our case studies, it appears that close utilization at the time of initial sawlog removal recovers more of the material than relogging. This, however, would depend on stand conditions and other factors not considered in these study areas.

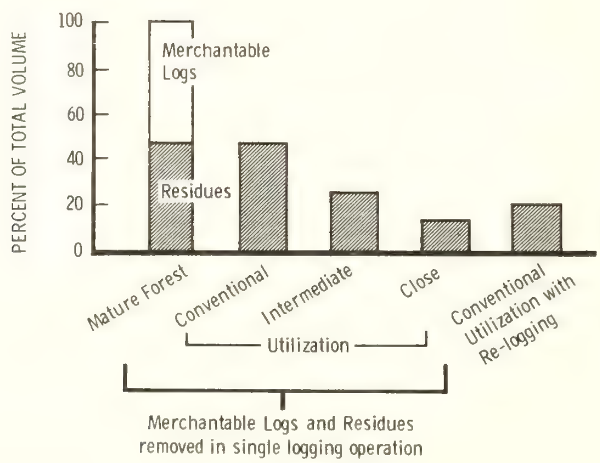

Figure 3.--Proportion of residue material in mature stands remaining under alternative utilization practices.

FACTORS INFLUENCING POTENTIAL UTILIZATION

Other papers in this proceedings examine the potential for residue utilization from both technical and economic perspectives. The total potential in terms of wood volume and use depends on three general factors: level of harvest, trends in utilization standards, and large scale uses.

Level of Harvest

Currently about 465 million ft^3 (13.1 million m^3) of residues are generated annually in the northern Rocky Mountains. About 355 million ft^3 (10 million m^3) of these residues accumulate in the six major forest types discussed in this summary. The level of harvest is projected to remain at present levels for the next decade or so, which means that if residues are removed at the time of regular harvest there is potentially available 0.3 to 0.4 billion ft^3 (8.5 million m^3 to 11.3 million m^3) of additional material.

If, as has been speculated, land use designation or restrictions on logging reduce the level of harvest, the volume of residues would be reduced accordingly. On the other hand, two potential sources of residues not included are: (1) material from thinning in young stands, which could add a modest amount, but is generally considered to be costly as fiber at this time; and (2) extensive salvage of dead or high risk trees. There are options to salvage log or prelog dead or high risk trees over large areas. This would essentially be the same as taking out all the residues in a short period of time rather than a continuing smaller annual volume removed along with the regular harvest. Two major problems would need to be solved: first, financing the extensive road system needed to reach scattered dead or high risk trees in a short time period; and second, providing equipment to successfully and economically remove these trees without adverse impacts on the remaining forest system.

Trends in Utilization

There has been a continuing trend toward greater utilization of wood fiber from any given logging unit because of increased demands for wood and improved methods of utilizing material formerly left as residue. When our studies began more than 6 years ago, we defined residue as material not meeting usual sawlog or veneer log specifications. Since then, material we originally classed as residue has been utilized to a greater degree. This has not been quantified in our studies, but several examples will illustrate the situation.

In western Wyoming and southeastern Idaho several mills were forced to adapt to using dead lodgepole pine. Bark beetle epidemics had almost eliminated green sawtimber.

A relatively new industry which produces house logs and log homes has been established in western Montana. Dead lodgepole is preferred, and often the value of this one-time residue is higher than that of green trees.

Throughout the western states, areas near forested land have seen a dramatic increase in the use of wood as a home heating fuel. In one area of southeastern Idaho it is estimated that from 25 to 40 percent of the total wood removed is for home heating fuel.

These trends indicate that a substantial portion of the region's 350 to 400 million ft^3 (10 to 11.3 million m^3) of residue material is already being utilized. The "residue" base actually shrinks, as mechantability standards are redefined.

Large Scale Use

The harvesting of northern Rocky Mountain timber for lumber and veneer production creates a seemingly inexhaustible supply of residue that has potential value. During the past few years important, but incremental, changes in residue utilization have occurred. In contrast to these small improvements, major increases in residue removal through industrial use appear possible. These possibilities include the expanded use of forest residues for pulp or fiber, as surplus sawmill and veneer mill residues decline; harvesting of forest residues for chemicals and wood alcohol; manufacture of densified fuel pellets for home or industrial use; and large scale use of all fiber material--wood, straw, whatever--for energy production.

If such large scale uses develop, guidelines will be needed to aid the land manager in determining the kinds and amounts of residue that should be left on an area to protect and enhance the forest ecosystem.

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APPLICATIONS OF A COST MODEL TO NORTHERN ROCKY MOUNTAIN RESIDUES

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ABSTRACT

Whatever decisions are to be made concerning the possible use of forest residues, questions always arise about the costs of collecting and transporting them to a place where they might be used. The residue cost model consists of a series of seven tables, which allow the estimation of the collection costs of the types of residues common to the northern Rocky Mountains. The cost tables were developed from published studies of both conventional logging and residue collection.

KEYWORDS: residue collection, residue utilization

Over the past several years, there has been much research directed at the potential uses of forest residues. The results have generally indicated that there are no technical problems in using residues, but we still find that they are not being used. The primary reason they are not is that the costs of obtaining the residues is greater than their value. In the spring of 1978, a cooperative study between the USDA-Forest Service Intermountain Forest and Range Experiment Station Forestry Sciences Laboratory and the University of Montana Bureau of Business Research was begun, with the goal being to develop a model for estimating the cost of collecting forest residues, and then using the model to estimate the cost availability of residues in this area.

The source of data for development of the cost model was published information related to conventional logging. Interviews with a number of operators who had experience in collecting residues indicated that it was really not much different from commercial logging, so that there was no need to develop a new data base just for residues.

The cost data collected from the many sources were summarized into a series of seven tables, which are given at the end of this report.

ORGANIZATION OF THE TABLES

The construction and organization of the cost tables represent a compromise between the need for the tables to be relatively easy to use, and the need to provide reasonable accuracy in the final cost estimate. To simplify the tables, some of the variables which one would expect to influence the cost of residue collection are not included, such as the species, or the slope of the ground. A number of variables, however, have such a strong influence on the cost that the tables include them. Some of the variables which must be considered are the size of the residue pieces, the skidding distance, the haul distance, and whether the material is to be chipped in the woods or hauled in whole.

Figure 1 shows the various combinations of tables that should be used to estimate the collection costs of various types of forest residues.

IMPORTANT VARIABLES

By far the most important variable in the cost of residue collection is the size of the residue pieces. The cost per piece of handling residues is smaller for smaller pieces, but the smaller pieces contain less material, so that the cost per unit volume is greater for smaller sizes. This relationship holds true in nearly every phase of residue collection, from falling of dead trees to the hauling of residues. Figure 2 shows the cost of ground skidding a distance of 300 feet (91 m). At volumes per piece above 10 cubic feet (0.3 m^3), the cost is relatively constant, but at smaller sizes, the cost rises very sharply, and goes off the scale of figure 2 at sizes less than one cubic foot (0.03 m^3) per piece. As a basis for comparison, a stick of wood four inches (10 cm) in diameter and 16 feet long (5 m) would contain about one cubic foot (0.03 m^3) of wood, and would weigh about 70 pounds (32 kg) green. A stick 12 inches (30 cm) in diameter and 16 feet (5 m) long would contain about 10 cubic feet (0.3 m^3) and would weigh about 700 pounds (317 kg).

The costs of falling and limbing, skidding or yarding, and loading all follow the same pattern of sharply rising costs with smaller sizes. The practical result of this relationship is that we cannot use average sizes of residues when estimating the cost of collection, as that would seriously underestimate the cost.

As an example, consider a quantity of logging residues where half of the total volume was contained in tops and small stems with an average size of one cubic foot (0.03 m^3), and the other half is contained in cull logs with an average size of ten cubic feet (0.3 m^3). The average size of all residues is then 5.5 cubic feet (0.16 m^3). From table 3, the cost of ground skidding a distance of 500 cubic feet (152 m) is \$16.40 per cunit (\$5.80 per m^3) (read at the closest table value of 5 cubic feet). However, the small material will really cost \$82.10 per cunit (\$29 per m^3) for skidding, and the larger material will cost \$8.20 per cunit (\$2.9 per m^3). The average cost is really (\$82.10 + \$8.20) /2 = \$45.15 per cunit (\$15.94 per m^3). By averaging the piece size, the cost estimate is only about one third of what it should be. Some averaging will be necessary in estimating costs, but care should be taken that the averaging does not include a wide range of sizes, especially of the smaller sizes. If the residues source is not relatively uniform in size, it should be divided into several size categories so that the cost can be estimated separately for each one.

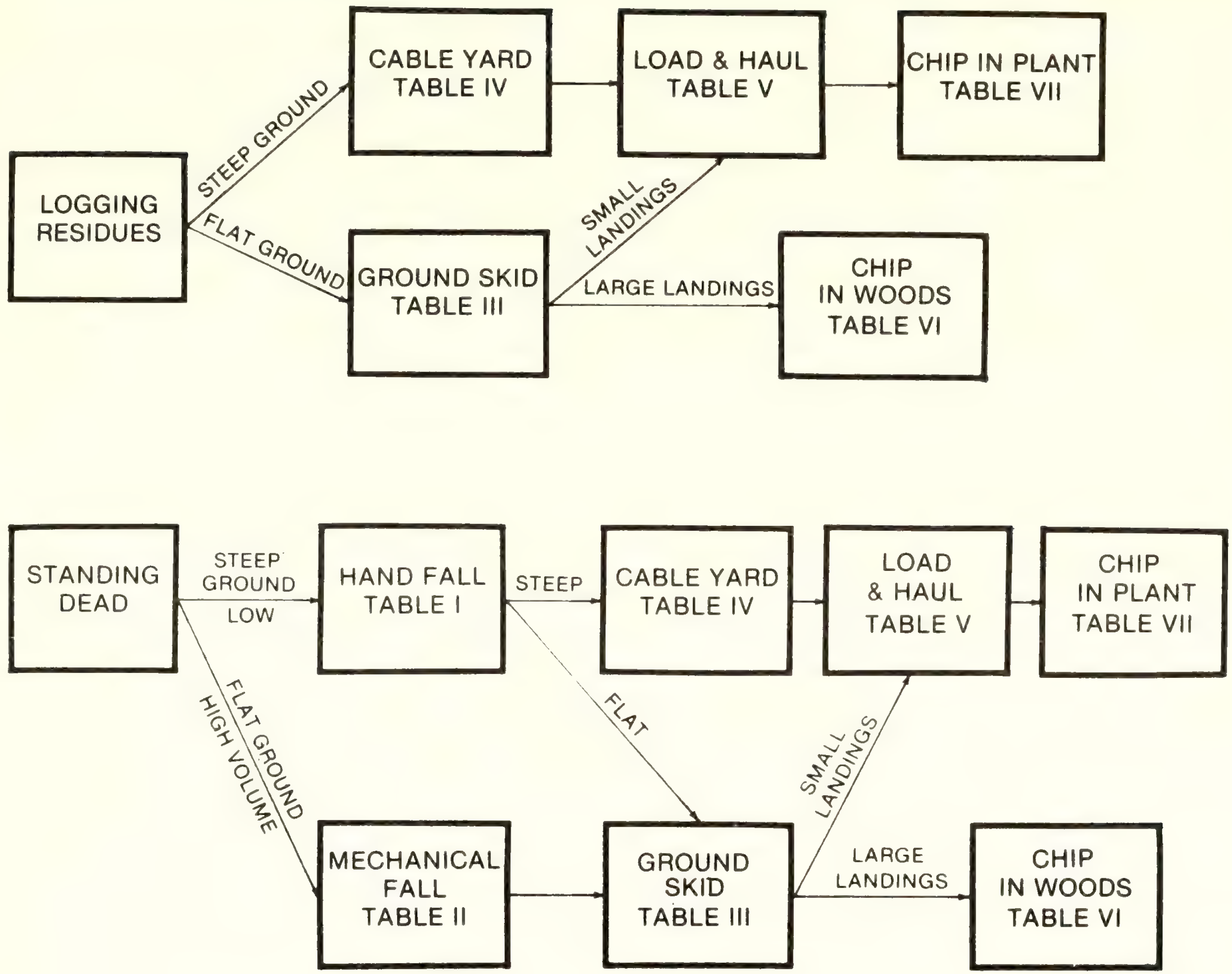

Figure 1.--Cost table selection guide.

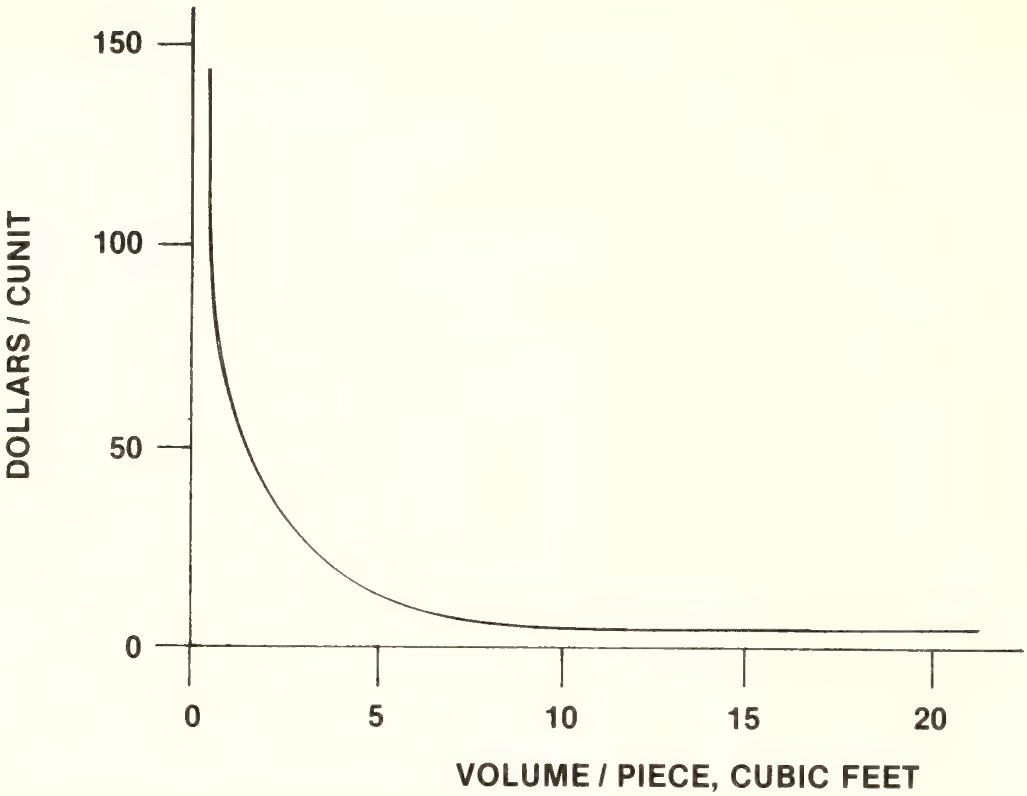

Figure 2.--Ground skidding cost, 300 feet, one way.

Distances for ground skidding, and for hauling to a central location also affect the cost, but the relationship is nearly linear, so that averaging does not cause a problem as it does with piece size. The amount of detail needed to obtain cost estimates can thus be reduced by using average skid distance and average haul distance.

The two remaining primary variables are the choice between ground or cable yarding, and the choice between chipping in the woods or centralized chipping. Ground skidding is always preferable to cable yarding because of the lower cost, but it can be used only where the ground is not too steep. As a general rule, if the average slope is greater than 30 percent, some form of cable yarding must be used. The per cunit cost of cable yarding is shown in table 4, and it should be noted that the cost is quite high. What this really means is that, except for some very large pieces, residues that must be cable yarded are not really economically available.

The choice between in-woods chipping or centralized chipping can be made partially according to the piece size. For piece sizes above about 5 or 10 cubic feet (0.14 or 0.28 m^3), it is cheaper to haul the pieces to a central location. For smaller pieces it appears to cost less to chip in the woods. However, the cost tables assume that conditions will allow efficient operation of in-woods chipping. The necessary conditions include sufficient volume to sustain a steady output, large flat landings, and good roads. These conditions are not often available in the Rocky Mountains, so that care should be used before assuming that in-woods chipping will be used.

Table 1.--Hand felling cost

d.b.h.		Felling only	Limbing only	Fell and limb
inches	cm		$/cunit[1]	
4	10	37.20	57.10	94.30
6	15	15.30	23.90	39.20
8	20	8.00	9.60	17.60
10	25	4.00	6.30	10.30
12	30	2.70	4.20	6.90
14	36	2.10	3.20	5.30
16	41	1.70	2.60	4.30
18	46	1.40	2.20	3.60
20	51	1.20	1.90	3.10
24	61	.90	1.50	2.40
28	71	.80	1.20	2.00

1/ to obtain $/m^3$, multiply tabled values by 0.353

Table 2.--Mechanical felling cost

d.b.h.		Fell only	Fell and limb
inches	cm	$/cunit[1]	
4	10	69.00	81.80
6	15	26.80	31.80
8	20	11.10	13.20
10	25	5.90	7.00
12	30	3.50	4.20
14	36	2.40	2.90
16	41	1.70	2.10
18	46	1.30	1.50
20	51	1.00	1.20

1/ to obtain $/m^3$ multiply tabled entries by 0.353

Table 3.--Ground skidding cost

Volume per piece		Volume per load[1]		One way skidding distance											
				feet											
				50	100	150	200	300	400	500	600	800	1000	2000	3000
				meters											
ft³	m³	ft³	m³	15	30	46	61	91	122	152	183	244	305	610	914
				$ /cunit[2]											
0.5	0.01	5	0.1	125.6	130.0	134.2	138.4	147.0	155.6	164.2	172.8	190.0	207.2	293.2	379.2
1.0	0.03	10	0.3	62.8	65.0	57.1	69.2	73.5	77.8	82.1	86.4	95.0	103.6	146.6	189.6
1.5	0.04	15	0.4	41.9	43.3	44.7	46.1	49.0	51.9	54.7	57.6	63.3	69.1	97.7	126.4
2.0	0.06	20	0.6	31.4	32.5	33.6	34.6	36.8	38.9	41.1	43.2	47.5	51.8	73.3	94.8
3.0	0.08	30	0.8	20.9	21.7	22.4	23.1	24.5	25.9	27.4	28.8	31.7	34.5	48.9	63.2
4.0	0.11	40	1.1	15.7	16.3	16.8	17.3	18.4	19.5	20.5	21.6	23.8	25.9	36.7	47.4
5.0	0.14	50	1.4	12.6	13.0	13.4	13.8	14.7	15.6	16.4	17.3	19.0	20.7	29.3	37.9
10.0	0.28	100	2.8	6.3	6.5	6.7	6.9	7.4	7.8	8.2	8.6	9.5	10.4	14.7	19.0
15.0 or over	0.42	150 or over	4.2	4.2	4.3	4.5	4.6	4.9	5.2	5.5	5.8	6.3	6.9	9.8	12.6

1/ Volume per load assumes 10 pieces per load to a maximum load of 150 cubic feet ($4.2 m^3$)

2/ to obtain \$ /m^3 multiply tabled entries by 0.353

Table 4.--Cable yarding cost.[1/]
$ Per cunit

Average Piece size Ft^3	m^3	Yarding cost $/cunit	($/$m^3$)
.5	0.01	769	272
1.0	0.03	390	138
1.5	0.04	261	92
2.0	0.06	197	70
3.0	0.08	133	47
4.0	0.11	101	36
5.0	0.14	82	29
10.0	0.28	43.2	15.2
15.0	0.42	30.8	10.9
20.0	0.57	24.8	8.8
25.0	0.71	21.3	7.5
30.0	0.85	19.3	6.8
40.0	1.13	17.2	6.1
50.0	1.42	16.0	5.6
60.0	1.70	14.0	4.9
70.0	1.98	12.4	4.4
80.0	2.26	11.1	3.9
90.0	2.55	10.1	3.6
100.0	2.83	9.3	3.3

[1/] The cost values shown are for yarding distances up to 1,000 feet. For yarding distances of 1,000 to 2,000 feet, increase the costs shown by 20 percent. Do not use this table for distances greater than 2,000 feet.

Table 5.--Loading and hauling cost

Average volume per piece		One way haul distance												
		miles												
		5	10	15	20	25	30	40	50	60	70	80	90	100
		km												
		8	16	24	32	40	48	64	80	97	113	129	145	161
ft^3	m^3	\$ /cunit[1]												
0.5	0.01	20.7	22.1	23.3	24.2	25.7	27.0	29.6	32.2	34.6	36.8	39.1	41.2	43.2
1.0	0.03	17.6	18.6	19.6	20.6	21.8	22.9	25.2	27.5	29.6	31.6	33.5	35.4	37.2
1.5	0.04	15.1	15.9	16.8	17.7	18.8	19.8	21.8	23.9	25.7	27.6	29.3	31.0	32.6
2.0	0.06	13.2	14.0	14.8	15.6	16.5	17.5	19.3	21.2	22.8	24.5	26.1	27.6	29.0
3.0	0.08	11.7	12.4	13.2	13.9	14.8	15.7	17.4	19.1	20.7	22.2	23.7	25.1	26.5
4.0	0.11	10.6	11.2	12.0	12.7	13.5	14.3	15.9	17.5	19.0	20.4	21.8	23.1	24.4
5.0	0.14	9.9	10.6	11.3	11.9	12.7	13.5	15.1	16.6	18.0	19.4	20.7	22.0	23.2
10.0	0.28	8.4	9.0	9.7	10.4	11.1	11.9	13.4	14.8	16.2	17.5	18.8	20.0	21.2
15.0	0.42	7.8	8.4	9.1	9.8	10.5	11.3	12.8	14.2	15.6	16.9	18.2	19.4	20.6
20.0	0.57	7.5	8.1	8.7	9.4	10.1	10.9	12.4	13.9	15.2	16.6	17.8	19.0	20.2
25.0	0.71	7.1	7.7	8.4	9.0	9.8	10.6	12.0	13.5	14.9	16.2	17.5	18.7	19.9
30.0	0.85	6.8	7.4	8.1	8.7	9.5	10.2	11.7	13.2	14.6	15.9	17.2	18.4	19.6
40.0	1.13	6.4	7.0	7.7	8.3	9.1	9.9	11.4	12.8	14.2	15.5	16.8	18.0	19.2
50.0	1.42	6.1	6.7	7.4	8.0	8.8	9.6	11.1	12.5	13.9	15.2	16.5	17.7	18.9
60.0	1.70	5.9	6.5	7.2	7.8	8.6	9.4	10.8	12.3	13.7	15.0	16.3	17.5	18.7
70.0	1.98	5.8	6.4	7.0	7.7	8.4	9.2	10.7	12.2	13.5	14.8	16.1	17.3	18.5
80.0	2.26	5.6	6.2	6.9	7.5	8.3	9.0	10.5	12.0	13.4	14.7	16.0	17.2	18.4
90.0	2.55	5.4	6.0	6.7	7.4	8.1	8.9	10.4	11.9	13.2	14.6	15.8	17.0	18.2
100.0	2.83	5.3	5.9	6.6	7.2	8.0	8.8	10.2	11.7	13.1	14.4	15.7	16.9	18.1

1/ to obtain \$ /m^3 multiply tabled entries by 0.353

Table 6.--In-woods chipping and hauling cost[1/]

One-way haul Distance		Barked chips[2/]	Not Barked chips[2/]
miles	km	---- $ /cunit[3/]	------
5	8	13.18	11.37
10	16	14.05	12.24
15	24	15.04	13.23
20	32	15.98	14.17
25	40	17.09	15.28
30	48	18.19	16.38
40	64	20.35	18.54
50	80	22.51	20.70
60	97	24.49	22.68
70	113	26.41	24.60
80	129	28.28	26.47
90	145	30.03	28.22
100	161	31.78	29.97

1/ Chipping only costs are: barked -- $9.04/cunit
not barked -- $7.23/cunit

2/ If the residues are to be barked prior to chipping, tables 1 or 2 (if used) must provide for limbing. If the residues are not to be barked, and thus contain bark in the chips, limbing is not required.

3/ to obtain $ /m^3 multiply tabled entries by 0.353

Table 7.--In-plant chipping cost

	$ /cunit	$ /m^3
1) Chip only[1/]	6.25	2.20
2) Handling costs[2/]	6.25	2.20
Total	12.50	4.40

1/ Chip only costs include chipper, labor, power, and limited yard handling.

2/ Handling costs include barking, bark and chip handling and storage, and screening of chips.

EXAMPLE COST ESTIMATION

Example A: High Volume Harvest of Dead Lodgepole Pine

Assume, for this example, that the residues are dead lodgepole, which is relatively uniform in size, with an average diameter at breast height (d.b.h.) of 10 inches (25 cm). It is on relatively flat ground with large landings available, so that mechanical falling and in-woods chipping are to be used. The average skidding distance is 400 feet (122 m). The trees will be chipped without barking, and hauled 40 miles (32 km) to a central location. The average volume per tree is 16.3 cubic feet (0.46 m^3). The relevant costs are:

Table 2:	Mechanical fall, without limbing	$5.90	($2.08/$m^3$)
Table 3:	Ground skid	$5.20	($1.84/$m^3$)
Table 6:	In-woods chip and haul, not barked	$18.54	($6.54/$m^3$)
	Total Cost	$29.64 per cunit	($10.46/$m^3$)

Example B: Logging Residues on Steep Ground

For this example, assume that the logging residues have the following size distribution:

a) 3 to 5 inch diameter, 8 feet long (8 to 13 cm, 2.4 m) 20 percent of total
b) 6 to 10 inch diameter, 16 feet long (15 to 25 cm, 4.9 m) 50 percent of total
c) 14 to 22 inch diameter, 24 feet long (36 to 56 cm, 7.3 m) 30 percent of total

The material is on steep ground, so that cable yarding must be used. It must be hauled 60 miles (96 km) to a central chipper, where it will be chipped for fuel, so that barking is not required. Because of the large difference in the piece size of the three categories, the cost must be estimated separately for each and the average cost found by using the percentage of the total as weights. The results are:

	Table 4	Table 5	Table 7	Total	% of Total
	$ per cunit				
a) .5 ft^3	$769.00	$34.55	$6.25	$809.80	20
b) 4.4 ft^3	$101.00	$19.01	$6.25	$126.26	50
c) 35.9 ft^3	$17.20	$14.20	$6.25	$37.65	30

Weighted Average Cost: $236.39/cunit

	Table 4	Table 5	Table 7	Total	% of Total
	$ per m^3				
a) 0.01 m^3	$271.46	$12.20	$2.21	$285.87	20
b) 0.12 m^3	35.65	6.71	2.21	44.57	50
c) 1.00 m^3	6.07	5.01	2.21	13.29	30

Weighted Average Cost: $83.45/$m^3$

These examples represent two of the extremes in the cost of collecting forest residues. There are residues that can be collected at costs which make them attractive sources of raw material for either products or fuel, but there are alos large volumes that are available only at exorbitant costs. When considering the entire forest residue resource, we must use care to remember that much of it is not economically available.

THE ECONOMIC AVAILABILITY OF FOREST RESIDUE IN THE NORTHERN ROCKY MOUNTAINS: A PRELIMINARY ANALYSIS

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ABSTRACT

The Bureau of Business and Economic Research and the Intermountain Forest and Range Experiment Station, Missoula, are involved in a cooperative research project to estimate the cost of harvesting and transporting forest residues to processing centers in the northern Rocky Mountains. Regionwide estimates are to be made based on detailed analyses of the volumes and types of forest residues available to selected individual manufacturing centers. The results of the analysis of the first manufacturing center are presented in this paper. The initial study area selected was Lincoln County, Montana, with Libby, Montana as the processing center. It appears from the analysis that substantial volumes of logging residue material would be available at a cost which would allow for its use in fuel and reconstituted wood fiber products as well as solid wood products.

KEYWORDS: residue availability, residue utilization, residue cost

The results presented in this paper are part of a cooperative research project by the Bureau of Business and Economic Research at the University of Montana and the USDA Forest Service Intermountain Forest and Range Experiment station in Missoula. The major objective of the project is to estimate the volumes of potentially utilizable forest residues in the northern Rocky Mountains, and the costs of harvesting and transporting this material to processing or manufacturing centers.

The task of making estimates for the northern Rocky Mountain area was approached on an individual manufacturing or processing center basis. The plan was to make a detailed analysis of the volumes and types of residue which could be delivered to selected manufacturing centers at various cost levels. The detailed analyses of the

selected manufacturing centers will be used in conjunction with projections of future timber harvest levels and locations to develop broad estimates of the volumes and costs of forest residues available in the northern Rocky Mountain area. This paper presents the results of the first attempt to develop cost estimates for a manufacturing center.

MATERIAL CONSIDERED IN THE ANALYSIS

Forest residues encompass an enormous quantity and variety of material. Virtually all of it is physically suitable at least as a raw material to manufacture reconstituted wood products or as a source of fuel. The major consideration in the increased use of forest residue is the cost of delivering the material to plants capable of utilizing the wood fiber.

The most available portion of the forest residue resource both physically and economically is that material which can be harvested in conjunction with conventional logging operations. The emphasis in this analysis was, therefore, placed on the logging residue component. Logging residue itself includes a varied amount and condition of material, ranging in size from branches and twigs to the boles of large snags, and in condition from sawlog quality material to unsound material with crumbly rot.

The focus of the analysis was further limited to logging residue that is both sound enough and large enough to be handled in conventional logging operations. This includes dead material, both standing and down, that has no defect, that has sound defect, or that has solid rot, as well as green material that is not of sawlog quality.

The minimum piece size was originally set at 8 feet (2.4 meters) in length and 3 inches (7.6 centimeters) in diameter, and then further restricted to a minimum piece size of greater than 2 cubic feet (.057 cubic meters). This was done because it was apparent from a preliminary analysis that the cost of removing material smaller than 2 cubic feet far exceeds the potential value of that material.

THE BASIS FOR THE ANALYSIS: PREVIOUS WORK AND TIMBER HARVEST DATA

Benson and Schlieter have developed estimates of the volume of residues in old growth stands for the major forest types in the northern Rocky Mountains. Withycombe has developed a model for estimating the cost of harvesting and delivering forest residues to plant sites in the northern Rocky Mountains.1/

A computer program developed with the assistance of Jim Ullrich, of the University of Montana Computer Center, has made further analysis possible. It uses both the forest residue data and the cost model in conjunction with site specific timber harvest information to estimate the volume and type of logging residue which can be delivered to a designated manufacturing center at various price levels.

1/ See Robert Benson and Joyce Schlieter, "Volume and Characteristics of Forest Residues in the Northern Rocky Mountains," and Richard Withycombe, "Application of a Cost Model to Northern Rocky Mountain Residues," in this publication of the proceedings.

The development of site specific timber harvest information involves the site by site construction of the timber harvest activity in a potential supply area for a so-called future typical year. The site specific information includes:

1) merchantable volume harvested by species;
2) method of removal (either by cable yarding or ground skidding);
3) the average skidding or yarding distance for each site, and
4) the haul distance to the manufacturing center.

Benson and Schlieter's residue volume data are used to develop factors to estimate from green merchantable volume the volume of the residue generated, classified by its condition, and its potential use for each site. The material is then further divided into categories according to piece size. Withycombe's cost model is used in conjunction with the timber harvest information, to estimate the cost of delivering the residue. The site-by-site data are then summarized for the supply area and the volumes can be sorted by cost and type of residue material for analysis.

The area selected to begin the study was Lincoln County in northwestern Montana, with Libby as the designated manufacturing center. The study was initiated in Lincoln County for a number of reasons, but primarily because it is a high timber producing area with a highly developed forest products industry -- in fact, Lincoln County is the highest timber producing county in the state. Because of the harvest level and predominant forest types, large volumes of logging residue are generated annually in Lincoln County, much of which remains unutilized and at present, uncommitted.

IDENTIFICATION OF THE POTENTIAL SUPPLY AREA

The potential supply area for Libby was designated as the timber supply area for the primary wood products manufacturers currently operating in Lincoln County. The reader should keep in mind that the supply area was defined somewhat arbitrarily and though it does offer the potentially cheapest logging residue available, it was established irrespective of the annual volume requirements of a potential user. If the evaluation were for a sulfate pulp mill, the supply area would have to be expanded considerably. In fact, it might be advisable to expand the supply area for plants with considerably lower raw material requirements, rather than use the more expensive logging residue material from within the supply area. For example, logging residue with a piece size of 100 cubic feet (283 cubic meters) that is hauled 100 miles (161 kilometers) might very well be cheaper to use than a 3 cubic foot (.085 cubic meter) piece hauled only 10 miles (16 kilometers). This paper deals only with the designated supply area. In the overall analysis the potential for drawing from an expanded area will also be evaluated. The supply area for the analysis encompassed much of Lincoln County and parts of adjacent counties in Montana and Idaho with a maximum haul distance of approximately 100 miles (161 kilometers).

THE DEVELOPMENT OF THE TIMBER HARVEST DATA

The annual timber utilization for all mills in Lincoln County in recent years has been slightly less than 200 million board feet, Scribner (979 thousand cubic meters) of timber. Of this material approximately 90 percent came from two sources -- from national forest lands, specifically the Kootenai National Forest and fee simple lands of the St. Regis Paper Company. Both the St. Regis Paper Company and the Kootenai National Forest provided us with detailed timber harvest and sale information.

The Forest Service timber harvest data were obtained from timber sales for calendar year 1978. The St. Regis Company data were from actual removals for 1978. The remainder of the harvest was estimated based on data from the above two sources.

RESULTS

Within the supply area as defined earlier an estimated 190 thousand cunits (537 thousand cubic meters) gross scale volume of logging residue would be available annually to Libby, Montana, from the designated supply area, at a cost of about $7.5 million in 1978 dollars (table 1). This represents an average cost of about $39 per cunit ($13.78 per cubic meter) delivered to Libby.

The volume figures in this analysis are expressed as gross in-woods volume. Estimates of loss due to breakage and defect range from 25 to 50 percent of this gross scale volume for logging residue. Preliminary estimates indicate that given this level of loss for breakage and defect, the cost per cunit for the net utilizable volume delivered will be approximately 50 percent higher than the costs indicated in this analysis.

The utilizable portion of logging residue was divided into three categories based on potential end use as follows:

1) material with no defect -- sawlog quality material
2) material with sound defect -- material suitable for some solid products such as house logs
3) material with solid rot -- material suitable only as a source of wood fiber but sound enough to be handled in a conventional logging operation.

All of the material is of course actually suitable as a source of fiber. However, the solid product uses of the no defect and sound defect material generally represent a higher value use.

An estimated 67 thousand cunits (190 thousand cubic meters) of no defect or sawlog quality residue would be available annually at an average cost of $46 per cunit ($16 per cubic meter). The sound defect category included an estimated annual volume of 33 thousand cunits (93 thousand cubic meters) of logging residue with an average cost of approximately $43 per cunit ($15 per cubic meter). The largest volume is in the solid rot category with an estimated annual volume of 90 thousand cunits (254 thousand cubic meters) available at approximately $33 per cunit ($12 per cubic meter).

The difference in average delivery cost among the three categories is due primarily to different piece size distributions in each of the categories. As indicated earlier, the total volume estimates and cost per cunit in all categories were calculated based on gross scale volume. Depending on the desired end use, the net scale volume of the material delivered would be somewhat lower and the cost per unit of utilizable wood fiber would be somewhat higher.

The figures shown in table 2 represent average cost figures. Because of the wide variation in not only piece size of the material, but also in the other factors contributing to the cost of delivery, there was quite a wide range in cost for each cunit composing the 190 thousand cunits (537 thousand cubic meters). In fact, the per cunit costs ranged from just under $15 per cunit to several hundred dollars per cunit with cost per cubic meter ranging from about $5 to in excess of $200.

Table 3 gives a much more detailed breakdown of the estimated volume of material that can be delivered to Libby from within the supply area. One of the things the computer model made possible was the identification of the volume of material which could be delivered to a plant in Libby for various ranges of costs. The cost ranges

Table 1.--Estimated logging residue available annually to Libby, Montana

TOTAL VOLUME (cunits)	190,000 cunits	537,000 cubic meters
TOTAL DELIVERY COST IN ROUND FORM (1978 Dollars)	$7,500,000	$7,500,000
COST (1978 Dollars)	$ 39 per cunit	$14 per cubic meter

Sources: Derived. Based on unpublished data from Robert Benson, Research Forester, Intermountain Forest and Range Experiment Station, Missoula, Montana; Richard Withycombe, Bureau of Business and Economic Research, University of Montana, Missoula, Montana; and the Kootenai National Forest and St. Regis Paper Co., Libby, Montana.

Table 2.--Average harvest and transportation cost of logging residue, by type, Libby, Montana

	RESIDUE VOLUME (000 cunits)	RESIDUE VOLUME (000 cubic meters)	AVERAGE DELIVERY COST per cunit	AVERAGE DELIVERY COST per cubic meter
No Defect	67	190	$46	$16
Sound Defect	33	93	43	15
Solid Rot	90	254	33	12
Total	190	537	39	14

Sources: Derived. Based on unpublished data from Robert Benson, Research Forester, Intermountain Forest and Range Experiment Station, Missoula, Montana; Richard Withycombe, Bureau of Business and Economic Research, University of Montana, Missoula, Montana; and the Kootenai National Forest and St. Regis Paper Co., Libby, Montana.

Table 3.--Volume of logging residue available, by type and by delivery cost category, in thousands of cunits

Cost Range	Residue Type: No Defect	Sound Defect	Solid Rot	Total
$ 0 - $10.00	0	0	0	0
$10.01 - $20.00	16	5	33	54
$20.01 - $30.00	21	14	32	67
$30.01 - $40.00	5	3	8	16
$40.01 - $50.00	7	3	6	16
$50.01 -$100.00	13	6	8	27
$100.01 and over	5	2	3	10
Total available	67	33	90	190

Sources. Derived. Based on unpublished data from Robert Benson, Research Forester, Intermountain Forest and Range Experiment Station, Missoula, Montana; Richard Withycombe, Bureau of Business and Economic Research, University of Montana, Missoula, Montana; and the Kootenai National Forest and St. Regis Paper Co., Libby, Montana.

used here are per cunit costs of $0-$10; $10-$20; $20-$30; $30-$40; $40-$50; $50-$100; and over $100 per cunit. The figures in the various cells are in thousands of cunits. The metric equivalents are shown in table 4.

For example, based on this analysis, no logging residue material of any kind is available to Libby for a cost per cunit of less than $10. For a cost per cunit of between $10 and $20, 16 thousand cunits of no defect material, 5 thousand cunits of sound defect material, and 33 thousand cunits of solid rot material would be available from within the supply area. Again, for between $20 and $30 per cunit, an additional 21 thousand cunits of no defect material, 14 thousand cunits of sound defect material, and 32 thousand cunits of solid rot material, and so on, would be available.

The high proportion of the total volume of the three residue types available in the lower cost categories (under $50 per cunit) seems to offer some encouragement for the increased utilization of logging residue material. Again, however, the reader should be aware that volumes are expressed in gross scale volume and may underestimate the cost per cunit of utilizable fiber by 50 percent. In the course of the overall project a major emphasis will be placed on expressing these volumes and the related costs per unit volume in units of utilizable wood fiber.

Table 4.--Volume of logging residue available, by type and by delivery cost category, in thousand cubic meters

	Residue Type			
	No Defect	Sound Defect	Solid Rot	Total
$ 0 - $3.53	0	0	0	0
$ 3.54 - $7.07	46	14	92	152
$ 7.08 -$10.60	59	40	91	190
$10.61 -$14.13	14	8	23	45
$14.14 -$17.66	20	8	17	45
$17.66 -$35.33	37	17	23	77
$35.33 and over	14	6	8	28
Total available	190	93	254	537

Sources: Derived. Based on unpublished data from Robert Benson, Research Forester, Intermountain Forest and Range Experiment Station, Missoula, Montana; Richard Withycombe, Bureau of Business and Economic Research, University of Montana, Missoula, Montana; and the Kootenai National Forest and St. Regis Paper Co., Libby, Montana.

A DEMONSTRATION OF A POTENTIAL APPLICATION OF THE COST MODEL

This section will focus on the solid rot logging residue to demonstrate how this analysis might be used. Table 5 includes an incremental and cumulative analysis of the solid rot logging residue material from within the designated supply area (Table 6 is the metric equivalent).

Column 1 again is composed of cost categories. Column 2 is the volume deliverable in thousand cunits in the various cost categories, and column 3 is the average per cunit cost of delivering the material in each cost category. Column 4 represents a cumulative total and illustrates what cumulative volume of material would be available at a cost equal to or less than the upper limit of the designated cost category. For example, for $20 or less per cunit, 33 thousand cunits are deliverable from the supply area; for $30 or less per cunit, 65 thousand cunits are available, and so on.

The fifth column represents a weighted average cost per cunit for the cumulative volumes. In other words, the average cost per cunit of delivering the 65 thousand cunits available for less than $30 a cunit is $20.

Table 5.--Incremental and cumulative analysis for solid rot logging residue

Cost Category	-- Incremental Analysis -- Volume (000 cunits)	Cost per cunit	-- Cumulative Analysis -- Volume (000 cunits)	Average Cost per cunit
$ 0 - $10.00	0	$ 0	0	$ 0
$10.01 - $20.00	33	17	33	17
$20.01 - $30.00	32	24	65	20
$30.01 - $40.00	8	35	73	22
$40.01 - $50.00	6	45	79	23
$50.01 -$100.00	8	65	87	27
$100,00 and over	3	191	90	33

Table 6.--Incremental and cumulative analysis for solid rot logging residue

	-- Incremental Analysis -- Volume (000 cubic meters)	Cost per cubic meter	-- Cumulative Analysis -- Volume (000 cubic meters)	Average Cost per cubic meter
$ 0 - $3.53	0	$0	0	$0
$ 3.54 - $7.07	92	6.00	92	6.00
$ 7.08 -$10.60	91	8.48	183	7.07
$10.61 -$14.13	23	12.36	206	7.77
$14.14 -$17.66	17	15.90	223	8.12
$17.67 -$35.33	23	22.97	246	9.54
$35.34 and over	8	67.49	254	11.66

This model might aid a firm in making several kinds of decisions. The following examples have been chosen to illustrate potential applications of the model.

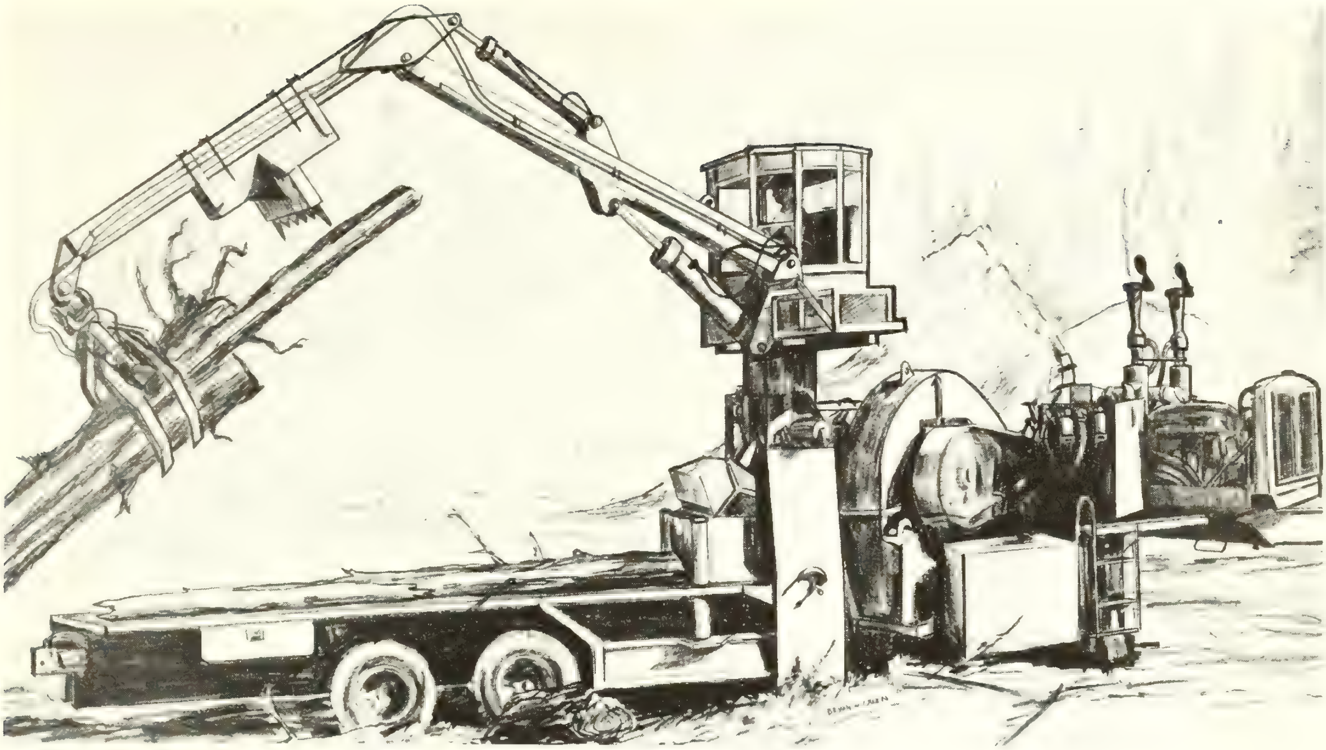
The first case assumes that a firm currently operates a power plant which allows some flexibility in the fuel mix; an example, would be one based on a solid fuel system that allowed the substitution of forest residue for a more conventional fuel such as coal, in greater and greater increments. In this case the firm would use the incremental cost analysis to evaluate the rate at which forest residue might be used as a fuel in place of a portion of the coal. If, as a substitute for coal, forest residue were worth more than $17 per cunit, the firm might consider using those first 33 thousand cunits and providing the remainder of its fuel needs with coal. If the cost of coal rose enough that as a fuel, forest residue were worth in excess of $24 per cunit, the firm would consider substituting the additional 32 thousand cunits with a marginal cost of $24 per cunit, and again providing the remainder of its fuel needs with coal.

A firm might also be faced with the decision of building a fuel generating facility for its plant. The cost of more conventional fuels would allow the firm to pay so much per cunit for forest residue as a fuel in a wood fired boiler -- let us say now $20 per cunit delivered in round form. This is a figure which, given recent and projected increases in the price of natural gas and fuel oil, is not at all unreasonable. The question facing the firm would then be whether sufficient quantities of forest residue were available at an average cost of $20 per cunit to supply a facility of this type. We see from our weighted average price that an estimated 65 thousand cunits of suitable material would be available annually from the supply area, for a weighted average price of $20 per cunit. This would be enough material to supply a rather substantial industrial fuel system.

The same type of analysis would, of course, be possible with the other types of logging residue. For example, this procedure could be used to determine what stumpage price and cost of green sawlogs would warrant adjustments in a firm's facilities, or investment in new facilities to use more dead material.

The model described here will have a number of potential uses. One of the major objectives for this model's development is to make possible broad range estimates of the volumes of forest residue available to processing centers throughout the northern Rocky Mountain area for various delivery costs.

In addition, the model is being constructed so that it can be easily adapted to facilitate more precise estimates of residue cost and availability on a localized level. The model is structured so that the cost factors and the residue volume factors can be modified to conform to local situations, and any suggestions for modifications to fit more localized cost and supply situations would be greatly appreciated.



HARVESTING OPPORTUNITIES

Wood residues on logged areas continue to create significant management and protection problems. YUM yarding, piling, burning, and other disposal activities are being practiced daily by timber operators and land management agencies. The most promising approach to utilizing this residue resource is through more efficient harvesting systems and practices, capable of recovering more of the total fiber resource at time of initial harvest. With few exceptions, relogging to recover material left as residue is neither technically nor economically attractive.

Research in improved harvesting system efficiency has taken two directions: (1) evaluation of the efficiency of existing systems when used to achieve close utilization standards, and (2) development of new harvesting systems and practices better suited to smaller, lower-value material. Research reported in this section includes field tests of conventional systems under a wide variety of Rocky Mountain timber conditions and operating situations; development of in-woods processing alternatives; and development of new concepts in harvesting technology.

The costs of recovering residue material constitute a primary barrier to improved utilization. The development and application of harvesting techniques that are physically and economically more efficient is a critical need. The research reported here, and continuing research of the same nature, addresses that need.

HARVESTING EFFICIENCY--A HISTORICAL PERSPECTIVE

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ABSTRACT

Many significant and far-reaching changes have taken place in the logging industry since its inception in the mid-17th century. But technological advances aimed at improved timber utilization have not come about quickly. It has been an incremental and continuous process, but progress can often be noted only by looking backward.

KEYWORDS: logging, harvesting, history

Although historical documents do not reveal the exact time, man probably began using wood at or about the same time he developed a taste for apples--no doubt first as a tool and shelter and later as a raw material for refined, durable goods. Why? Because wood, millions of years ago, had the same desirable qualities as it has today. Namely, it produces heat when burned, it is easy to work, its strength/weight ratio is excellent, and it is renewable. Because of my admiration and respect for loggers of all eras, please note I did not say wood was easy to obtain.

"Harvesting" of timber is a term applied to many sequential activities. It begins with the designation of what timber is to be removed and what is to be left and ends with reforestation. The actual cutting of timber and its movement from the woods to the mill is one of the harvesting activities. This I refer to as logging--and it is the activity at which most of my comments will be aimed.

Because many changes have been made in logging equipment and techniques, I think it is proper for us to pause at this time and look back, if for no other reason than to allow a redefinement of perspective. Many years ago, a farsighted individual named Renan predicted "that the 20th century will spend a great deal of time picking out of the wastebasket the values the 19th century threw into it." So during the next few minutes, let's take a look through the logger's wastebasket.

When the United States formally declared its independence, our country consisted of 13 States, many more wild animals than people, and seemingly limitless tracts of forests. Philadelphia was the largest city, with 34,000 people. Nine out of 10 new Americans lived in the country, scattered along the eastern seaboard

from Maine to northern Florida. Yet, because of the high birth rate and large influx of immigrants from the Old World, the population of both town and country was increasing rapidly.

Still, in 1776 the original states contained mainly expansive wilderness and very few farms. To the colonists, vast eastern forests of more than a million square miles represented a dark and impenetrable place that harbored wild animals and "dangerous" Indians. But these colonists were determined and tough. They would remove this obstacle and then plant their crops. True, they used trees for ships, houses, fuel, tools, etc., but there were more than they could use. They had to "let daylight in," and this they accomplished with unrelenting determination.

Most settlements had a "lumbering" industry because of the abundance of timber, but these were on a small scale, used primitive methods, and supplied mainly local needs. In the beginning, logs were split with a froe or sawn on a pitsaw.

Supposedly, the first power-driven sawmill in America was established in 1633. Depending on which book you read, it was in Maine, New Hampshire, Pennsylvania, New York, or Virginia. The number of sawmills grew quickly. Most were waterpowered and were therefore located along streams which also provided transportation for the logs. Soon, gangsaws were developed that could cut many more logs per day and the problem of keeping logs at the mills arose.

Because of increasing populations and growing export markets, lumbering became a rapidly expanding enterprise. By 1682, Maine alone had 24 sawmills. Consequently, logging operations had to expand as well to keep the mills supplied with logs.

The lumbering industry as we know it today began in the Northeast. White pine was the "king tree." Almost all of the northeastern states had an apparently never-ending supply of this great species, but the region we know as Maine today was particularly suitable for large-scale commercial logging. This was because of the desirable combination of uninterrupted expanses of timber and the preponderance of rivers and streams to float logs to the mills.

Men with money and vision began buying up timberland in Maine. Much of it was purchased at the rate of 12.5 cents per acre. It is reported that a Philadelphia banker and politician by the name of William Bingham purchased 2.1 million acres of pine and spruce in one tract in the Penobscot country in 1790.

Immigrants from Scotland and Ireland as well as skilled French-Canadians provided the bulk of the manpower needed to cut and move this timber.

The method of logging was pretty much standard. It was called "white water logging." With the coming of the "fall freezeup," small armies of loggers took to the woods. Logging camps were located up the streams from the mills. Trees were felled with axes and bucked to length with crosscut saws. The logs were then manhandled onto a crude skidding device called a go-devil to yard to the main road. The go-devil was a section of a forked birch that had a crosspiece fastened midway of the V; it was pulled by a team of horses. At the main road, the logs were loaded with the help of gravity onto sleds and pulled by oxen to the streambank. Throughout the bitter cold winters, sled loads of logs were hauled to the river's edge and stashed there in gigantic piles. To make the sleds move with greater ease, water was sprinkled on the snowpacked road during the night. By morning it was frozen hard and slick. Snubbing lines attached to stumps were used to slow the sleds when going down hills.

Although the bitter cold and deep snow provided miserable working conditions, winter logging was conventional for many years. Available technology permitted few options.

When spring finally arrived and the streams began flowing, the piles of logs were pushed into the rushing waters by loggers with long, steel-tipped pike poles. Thus began the spectacular log drives downstream to the mills. Along the way the logs would inevitably jam and have to be freed by the daring drivers. This was one of the most dangerous jobs of the white water logger. Yet most survived the drives to "blow in" their wages of about $20 a month in the mill towns where wine, women, and song were always in plentiful supply.

The basic tools and equipment used in early logging consisted of the ax, one-man crosscut saws for bucking, sleds, a type of cant hook, and pike poles. Power was supplied by man, oxen, and horses aided by gravity.

Axes have been in use since the stone age--but refined over time into finely balanced and very effective tools.

Saws are of more recent times, although used in Europe as early as the middle of the 15th century. Crosscuts became widely used in this country in the early 1800's. Almost all of them were manufactured in America because imports from Europe were expensive and difficult to obtain. Crosscut saws increased log production considerably and reduced wood losses from chips previously produced by axes. For reasons difficult to imagine, until 1880 saws were used for bucking only. Why it took 40 years for fallers to realize that saws could be made longer and used by two men to fell a tree is not understood. But when axes gave way to felling saws, production climbed with a resultant decrease in safety hazards. The direction of fall of a sawn tree was more predictable than a tree felled with an ax. The ax was still used to put in the undercut.

Several tools and devices that made logging easier, safer, and often more productive were invented and put into use in the Northeast. The Peavey was invented and first manufactured by Joseph Peavey near Bangor, Maine, in 1858. A large boom for sorting logs was devised in 1825, and this idea has been used widely. The Bangor snubber, a device for controlling the speed of sled loads of logs on steep hills, was invented by Bangor men sometime in the 1830's. In the late 1800's, sluiceways and steampowered conveyers were introduced that speeded log delivery to mills tremendously.

It must be mentioned that new developments in logging practices were often spurred by new developments in milling and processing techniques. As the mill capacity increased, more logs were needed. This is still true today.

The first real increase in lumber production came with the first steampowered sawmill. The Bath Steam Mill Company of Bath, Maine, supposedly built its first mill in 1821. By 1850, 36 steampowered sawmills were in operation in the State of Maine.

The development of the circular saw greatly increased production over the old sash or up-and-down saws. They were in wide use in Maine by the middle of the 1800's. Saw filing became an art shrouded in secrecy. Gang-saws that used 20 and more blades on the same rig soon appeared on the scene, again to boost production at the mills.

Each of these innovations increased the appetite of the mills--one that had to be satisified--and the loggers would do it!

After about a century of intensive logging, it became obvious to most lumbermen that the forests of Maine were really not inexhaustible. Enterprising people began looking around for new timberlands as early as the 1830's. Some operations were moved to upstate New York and western Pennsylvania, where lumbering was already proceeding at a rapid pace. The Erie Canal, which was completed in 1825, would subsequently move thousands of loggers westward and millions of feet of lumber eastward. Albany, New York, was the biggest lumber market in the world for 40 years.

The expansion of the logging frontier continued westward until its next major stop in the vast white pine forests surrounding the Great Lakes.

This migration from the Northeast had its beginning in 1836 with the purchase of a tract of timberland on the St. Clair River in Michigan. The purchaser was Charles Merrill of Lincoln, Maine. Many more such purchases were soon made by eastern lumbermen--all at the going rate of $1.25 an acre for public domain lands.

The timber in the Lake States was bigger and thicker than anything ever seen in the East--surely more than could be cut in 1,000 years. And these were great streams for driving logs--the Saginaw, An Sable, the Bad, the Rifle, etc. Plenty of snow, too, for winter logging, still the conventional way.

The first sawmills were established in the Lake States about 1832, but the region did not become the center of lumbering activities until after the Civil War. By 1870, the Lake States became the leader in lumber production and remained so until 1900 when the South took over. By the early 1880's there were 112 mills along the Saginaw River, cutting a combined total of slightly more than a billion board feet of lumber annually.

The demand for lumber was constantly increasing, pushed upward by the rapidly rising population in America. Between 1820 and 1870, the United States population quadrupled. Thus, the associated demands for forest products and new homes had risen in priority to those for export products such as ship masts and staves.

Again, technological advances in sawmilling led to demands for more logs. Lumber making in Maine had been slow compared to that of the Lake States. Although a bandsaw had been invented in England in the early 1800's, it took 75 years for it to reach America. The first bandsaw headrig appeared in the Lake States in the 1880's. This saw could easily outproduce the old circular saws and, in so doing, left less sawdust.

Other developments followed to complement the bandsaw. Log handling devices that loaded logs onto the carriage and the bull chain that moved logs from the log pond to the mill were developed by Michiganers. The log pond was rendered ice-free by running steam lines from the mill into the pond. Now mills could cut all winter.

People with inventive abilities had a field day. Someone devised a rig known simply as "the big wheels." This was a pair of wooden wheels, each 10 feet in diameter, set on an axle connected by a long tongue or pole. A log was straddled by the big wheels and chained to it. When the pole was pulled by oxen or horses, the front end of the log would be lifted slightly off the ground. This became the first wheeled skidder. Roads were not needed because the axles had sufficient height to clear stumps, rocks, etc. The biggest effect was to make summer logging practical. If the mills would work all winter, then the loggers would work all summer.

All of these increased activities and new processing developments hurried things along in the woods as well, for it was the logger's sole job to keep the log ponds at mills full of logs.

Logging activities in the Lake States started in lower Michigan, moved to the upper peninsula, to Wisconsin, and finally, to Minnesota.

Winter logging was conventional in the Lake States, also. Sleds were the primary means of moving logs from the woods to the streams. A common load for one sled drawn by a team of horses was 60,000 pounds. Stewart Holbrook describes a fantastically large sleigh load of logs in his book entitled "Holy Old Mackinaw." The load was put together in northern Michigan to show off at the Columbian Exposition of 1893 held in Chicago. The load, made up of logs 18 feet in length, was 33 feet 3 inches high and scaled 36,055 board feet. One team of horses pulled it with ease from the woods to the shipping point, but it took nine railroad flatcars to move the logs and sleigh to Chicago.

Logging camps expanded rapidly in size and number of workers. Unable to hire enough workers from local areas or the Northeast, thousands of Canadians from the maritime provinces were recruited by the timber barons. They also imported Scandinavians from Norway, Sweden, and Finland with great success.

Conditions improved in logging camps, also, with a resultant increased output of logs. Camps became cleaner; hence, less sickness and disease. Above all, the variety and quality of the food improved steadily. Good cooks became almost as important as good bosses. The introduction of canned foods helped greatly to improve the bill of fare. The number of items in the camp stores steadily expanded to provide loggers with their needed personal items.

Railroad logging came to Michigan in the 1870's, but the early locomotives were practical only on fairly level ground. The first successful logging railroad in the United States was the Lake George and Muskegon River Railroad built in 1876-77 in Michigan. Reportedly, there were 89 logging railroads running more than 450 miles of track in Michigan by 1889.

The year 1881 brought two highly significant developments to the logging industry. In this year new technology that utilized steam revolutionized logging forever. Steampower had been used at sawmills for 40 years, but loggers still depended on brute force provided by man or animal, water, or gravity to move logs.

Now in 1881, Ephraim Shay of Michigan developed the steampowered, gear-driven, railroad locomotive. With the advent of the railroad, sawmills were located inland along the rail lines. The railroads provided transportation for the lumber and made possible the expansion of Lake States logging into Wisconsin and Minnesota.

And out in the West, a Californian named John Dolbeer invented the steam donkey. Horses and oxen could rest at last. The donkey, with first rope on its capstan-like drums and later wire cable, was used to yard and load logs. Both the donkey and the locomotive served as the power of the forests until gradually replaced by the internal combustion engine.

Maine loggers were still contributing to logging progress. In 1886, Horace Butters, then living in Ludington, Michigan, invented the Horace Butters' patent skidding and loading machine. This gigantic and complicated system was the forerunner to cable logging rigs used today in more refined forms. Butters' setup consisted of two spar trees with guy ropes and a trolley strung between the spars. A carriage was pulled along the trolley by a line from a steam donkey. Logs were lifted out of the woods and pulled to one of the spars. There, another donkey and

rigging loaded them onto railroad cars. This skidding device never really caught on in the Lake States, but it was used effectively in the South to log the bayous, and it was used extensively in the West in various forms and configurations.

Lumbering in the Lake States continued at a frantic pace until the turn of the century. Chicago was the center of lumber merchandising and use. Immense quantities of wood were needed to rebuild Chicago after the disastrous 1871 fire.

Then, as it happened in the East, the magnificent stands of white pine were exhausted, and it was again time to move on--this time to the South and to the Far West. About one-fourth of the migrating loggers from the Lake States moved to the South; the rest went West.

Lumbering activities had been underway for some time in the South and in the West, but at fairly low levels of intensity. Accelerated logging in the vast pine forests of the South began in the 1870's. Soon after the Civil War, several sawmills were built along the Gulf Coast. Mobile, Alabama, became a major lumber port. Since the South was already settled and populated, a local labor supply was already available.

Only the most accessible places in the South were logged at first. Techniques used were much the same as in the Lake States. Rivers and ditches were used to float and move logs to the mills. Oxen pulled logs, hooked together or on carts, to these waterways.

The coming of the railroad opened up markets in the North for southern pine lumber. Lumber production rapidly increased throughout the South. The region supplied 39 percent of the total United States production in 1900; in 1920 this jumped to 52 percent.

Timber production in the South was different from that in the East and Lake States. Because of comparatively rapid growing conditions, second-growth stands succeeded the virgin stands in a relatively short time. This, coupled with excellent protection and other intensive management practices, accounts for the fact that the South today still produces about 30 percent of the Nation's lumber.

Logging and sawmilling began on a limited scale in the Northwest some time in the late 1820's. Lumber was first sawn on pitsaws powered by two men at the rate of 150 board feet per day. Later, a mechanical saw powered by water produced 3,000 feet per day.

California began producing some redwood lumber a few years later, but West Coast logging remained at a low level because a substantial local market for lumber did not exist. No more than 25,000 people lived along the entire West Coast in 1847. To the East there was only wilderness for some 2,000 miles.

The market problem was solved in 1848 with the discovery of gold--appropriately enough at a sawmiller's site in California's Sierra foothills. The migration of people from around the world to mine the gold created a demand for wood far above the local wood producers' capability.

Sawmills and logging operations quickly sprang up along the California coast and on up to Oregon and the Puget Sound in Washington. The methods were crude at first, but steady progress was made, and new developments such as the circle saw and steampower were eagerly adopted. With soaring demands for lumber and increasing mechanization, logging operations were conducted in all seasons of the year.

The opening of transcontinental railroads to Portland in 1882 and across the Cascades to Puget Sound in 1887 again greatly expanded the markets for western lumber. By 1880, western producers were cutting about 700 million board feet per year.

The Indians along the northwest coast of Washington and in southern Oregon were the first loggers to cut timber in these regions. They used the huge cedars, spruces, and pines to build canoes and large cargo boats.

The gigantic western conifers presented new challenges to the western loggers' ingenuity. A single fir tree could be 10 feet in diameter and weigh 100 tons. Redwoods and cedars were much larger.

At first, hand logging was done, but this was feasible only where trees grew next to rivers or streams. It was also slow and backbreaking. Oxen were later used to skid strings of logs to streams. Big wheels pulled by oxen were used on somewhat flat, dry land. Various kinds of chutes and flumes were devised to move logs down the hills.

The skidroad came into use on the Puget Sound in the early 1850's. This was a wide, well-engineered and cleared trail over which strings of logs were skidded by oxen and horses. Skids made from thick timbers laid crosswise on the trail like rail ties reduced the drag of the logs. Grease was applied to the skids to make the going easier. Effective as it was, the skidroad could not be used on hills too steep for oxen nor at greater distances than what the animals could endure.

The term skidroad later took on another meaning. When used as two words, both capitalized, Skid Road referred to the streets in any logging town that were brightly lit and lined with saloons, honky-tonks, restaurants, and lodging houses. This was the place the loggers went to "blow 'er in" after the long months in the logging camps. The term was eventually changed to Skid Row by some unknowing writer.

The log chute was the first device that enabled the loggers to reach up onto the steep slopes for the large, quality timber. Furthermore, it did not demand sheer muscle power from men or beasts. Gravity did most of the work. Chutes were basically long troughs made from peeled trees. The inside surface was generally greased to ease the movement of the logs. A chute built above the Klamath River in Oregon was 2,650 feet long and reportedly carried logs at speeds up to 90 miles per hour.

Flumes were also used, although mainly for lumber. They were made of lumber to carry sawn boards to the bottom land for shipping or reloading. Flumes were much longer than chutes--sometimes 40 or 50 miles. They were really small manmade rivers, since moving water was used to carry the lumber.

But it took the steam donkey and the Shay locomotive to get western logging highballing. With the coming of improved wire cable in the 1890's, the steam donkey was used to lift, pull, and haul logs in just about any imaginable configuration. Dolbeer's donkey was, of course, the necessary ingredient for successful ground-lead logging. It also spawned the development of high-lead logging which required spar trees and a daredevil high climber.

The steam donkey had a definite economic effect on logging. Skidding costs on one operation along the Columbia River reportedly dropped from $4.50 to $2.10 per thousand board feet when donkeys were used instead of oxen. Production almost doubled when the high-lead took over.

Commercial logging came to the Inland Empire in the mid-1840's. The importance of this region was based on the production of western white and ponderosa pine. The first mill on record in Idaho was built in 1840 at Lapwai. It primarily supplied the growing lumber needs of the mining industry.

The first mill reportedly built in Montana was at Stevensville in the late 1840's. These were combination gristmills and sawmills powered by water. Logging methods were similar to those used in the Lake States. Logs were hauled by animals to stream banks and floated down to mills in the spring. On more level land, big wheels, which were the forerunners to the more improved skidding arches and log flumes were used. Steam donkeys combined with locomotives accelerated the logging pace near the turn of the century.

The pine loggers of the Inland Empire were again prodded by the sawmillers. Someone filed teeth on the rear edge of a bandsaw blade so it cut when moving both forward and backward. The double cut band increased production noticeably and other equipment in the mill was streamlined to keep pace.

The logging and milling of pine developed rapidly. Lumber production in Idaho went from 65 million feet in 1898 to 500 million in 10 years. Loggers watching the highballing movement of logs on a high-lead setup were certain this level of mechanization would never be exceeded. But it wasn't long before someone put up two spars and skyline yarding was born.

Further developments revolutionized logging again and again. The application of the internal combustion engine to the woods in the 1920's spelled doom to the steam donkeys and locomotives. First, gasoline, and later, diesel engines, gradually took over the role steam had played so effectively. Mobile wheeled and track-type tractors became common and proved to be very efficient in skidding. Diesel-powered trucks pulling highly maneuverable log trailers came into use. They could go almost anywhere when combined with modern road-building equipment and techniques. Winches with wire rope were added to the tractors as a further refinement.

About this same time, the power saw was being developed by several different innovators. This proved to be the most important technological contribution to the logging industry since the steam donkey and the locomotive. They reportedly cut felling and bucking time in half.

The first power saws were steam operated, but electric saws came on the scene shortly thereafter. They were huge, heavy, and cumbersome, but improvements were continually being made. The earliest production saws with gasoline engines came from Germany, but this source dried up with the advent of World War II. The Titan 1/ saw, manufactured in Seattle, was supposedly the first power saw built in the United States. This was about 1940. Several followed closely, including Mall, Disston, McCullough, Lombard, and Homelite.

Extensive use of power saws began after the war and quickly retired the axes and cross-cut saws that had been the standard for so many years.

Log loading and unloading devices have been improved greatly over the years. Modern, self-propelled, hydraulic-powered machines now lift an entire truck or rail car load at one time.

1/ The use of trade, firm, or corporation names does not constitute an official endorsement of, or approval by the U. S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

Rapid advancements have been made in the development of rubber-tired articulated skidders. With their great maneuverability, high clearance, and short turning radius, they have probably had the greatest impact on logging since the development of the chain saw.

The 1960's saw widespread use of felling shears, tree harvesters, and in-the-woods chipping. They continue to be used on relatively level ground and more extensively in pulp operations.

Cable yarding continues at a high level in the West and the Inland Empire. New, more sophisticated and smaller mobile yarders are becoming popular. Their use grows with increasing environmental concerns and the need for thinning overstocked stands.

Overall, giant strides have been made in recent years in the advancement of logging technologies. Helicopter and balloon logging is commonplace. Machines that cut, buck, delimb, and carry are in wide use, and fast-moving trucks haul large loads of logs to market on modern paved highways. And this is as it should be. A noted philosopher by the name of Bacon once said, "He that will not apply new remedies must expect new evils."

Now that we have looked back through the pages of logging history, we might properly ask, "have things really changed, or is it like the cynic said--'Change is something which is often identified with progress, like a woman moving furniture around, or an office manager shifting offices'?" In 1776, men were coping with the problem of how best to move logs from the woods to the mills. We're doing the same thing today. Maybe there is something to the cliche, "The more things change, the more they remain the same."

But there have been changes to be sure. The beginning and end result may be the same, but the ways of reaching it are quite different. Conditions have changed dramatically. Trees today are smaller than yesteryear--and they grow on some of the darndest places. Many of the logs brought in today would have been left in the woods as recently as 2 or 3 years ago.

Yet, changes have also occurred at the other end of the scale. Markets exist today for a much greater array of wood products than in earlier years. Opportunities for better utilization are arising. Pulp mills and particleboard mills, for example, use small roundwood of lower quality. Wood chips and sawdust are used widely to produce energy.

These are exciting times. New technology coupled with new markets and products provide the key.

The important thing to remember is that change is often not readily noticeable because it comes so slowly. It is usually an incremented and continuous process. It does not happen overnight. It is evolutionary many more times than revolutionary. Often we must look back to see progress. But it does occur with patience and perseverance and usually with everlasting beneficial effects.

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INTENSIVE UTILIZATION WITH CONVENTIONAL HARVESTING SYSTEMS

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ABSTRACT

Forest residues utilization research has included case studies of the efficiency of existing harvesting systems in achieving close fiber utilization. Field evaluations included the use of in-woods chipping systems in gentle terrain; crawler skidder systems in gentle terrain; and skyline systems in steep terrain. In each situation, utilization standards ranged from conventional saw log utilization to near-total utilization of available fiber.

Intensive utilization has been achieved concurrent with saw log harvesting, rather than through postharvest salvage. The total costs of harvesting merchantable material and residue together are partitioned to derive costs of residue recovery. Costs of recovery vary significantly among the case situations studied, and also vary with the method by which costs are allocated. Residue recovery costs commonly run \$30-\$60 per dry ton (\$33-\$67 per tonne).

KEYWORDS: forest residues, timber harvesting, wood residues utilization, logging systems, timber harvesting productivity.

THE HARVESTING TASK

Although timber harvesting practices have improved dramatically in recent years, large volumes of wood residues and salvable material remain unused in the Rocky Mountain area. More complete and efficient utilization of this resource poses a major challenge. National projections predict substantial continued increases in demand for wood and wood fiber-based products. Environmental considerations also favor extending the use of wood, a renewable natural resource that can be processed with less energy and less attendant pollution than alternate materials. Increasing interest in biomass fuels for supplementary power generation further emphasizes the undeveloped potential of the wood residue resource.

Excessive volumes of forest residues result in significant management problems: fire hazards, reduced wildlife use, degraded esthetic quality, difficult regeneration, and costly disposal. Harvesting and utilization practices that facilitate more complete use of these residues can help meet national needs for wood products and solve critical forest resource management problems.

Forest residues remaining on logged sites include small trees, cull and broken logs, tops, and dead timber. The most immediate opportunity to increase utilization of this material is to remove it in conjunction with conventional harvesting operations. A primary barrier to improving utilization, however, is the added cost of recovering residue material. Typically, the value of residues will not cover the costs of harvesting them. Harvesting systems and practices are needed that can more effectively and efficiently recover residue.

The residue utilization research program has included both the evaluation of existing harvesting systems and the development of new harvesting concepts for achieving close fiber utilization. This report covers the field testing and evaluation of harvesting systems in common use under various stand and terrain conditions and silvicultural systems encountered in the Northern Rockies.

EVALUATING EXISTING SYSTEMS

Recovering residue material with conventional harvesting systems, in conjunction with the harvest of merchantable material, offers potential advantages. Conventional logging systems are available, are in place, and involve no radical changes in technology. Further, they require no new or added capital investments, and no significant changes in job skills or training requirements. The costs of practicing intensive utilization with existing systems are largely unknown, however, as are the technical problems that may be encountered.

Research efforts reported here were directed toward defining costs of residue recovery with three conventional systems: skyline logging on steep terrain; tractor logging on gentle terrain; and in-woods chipping teamed with a ground skidding operation on gentle terrain. Because the silvicultural prescription has a significant effect on most harvesting costs, a range of silvicultural practices were included on two sites. Utilization standards for cutting units on each site included conventional saw log utilization and one or more intensive fiber utilization standards. Intensive utilization prescriptions specified the removal of material down to a defined size and quality class, and allowed the contractor to accomplish this jointly with removal of the "merchantable" portion of the timber. The three harvesting operations, and associated utilization standards, recovery, and costs, are described in following sections.

Skyline Harvesting--The Coram Site

The Coram study site is located on Coram Experimental Forest, on the Hungry Horse District of the Flathead National Forest. The site typifies old-growth western larch/Douglas-fir stands on steep slopes. Elevations range from 3,900 to 5,300 feet (1 188 to 1 615 m), and annual precipitation is in the 25- to 35-inch (64 to 89 cm) range. Western larch and Douglas-fir are the predominant tree species, although subalpine fir, Engelmann spruce, western hemlock, and birch also occurred in intermixture on the harvested units.

Steep slopes and operating constraints dictated the use of either aerial or cable yarding systems capable of relatively long reach (1,000 to 1,200 feet) (305 to 365 m) and at least partial suspension of logs being yarded. Skyline yarding systems were

used--a running skyline system where both up- and downhill yarding were required (fig. 1), and a live skyline where uphill yarding alone was adequate. Silvicultural prescriptions included in the field tests, and the utilization standards practiced, are described in table 1.

Figure 1.--A running skyline system was employed on the Coram site to provide both up- and downhill yarding capability.

Table 1.--Harvesting treatment specifications for cutting units, Coram site

Silvicultural system	Cutting specifications	Utilization standards
SHELTERWOOD	All trees designated by utilization standard cut; approximately half the volume in 7"+ (17.8 cm) d.b.h. trees left, aiming for good height and species diversity.	(1) Conventional: logs to 8'x5½" (2.4 m x 14 cm) top, one-third sound, removed from all 7"+ (17.8 cm) d.b.h. trees cut, green and recently dead.
		(2) Intermediate: logs to 8'x3" (2.4 m x 7.6 cm) top, one-third sound, removed from all cut trees 5" (12.7 cm) d.b.h. and larger, and all standing and down dead timber.
		(3) Intensive: all cut green and recently dead trees 5" (12.7 cm) d.b.h. and larger removed tree-length; all green trees 1"-5" (2.5-12.7 cm) d.b.h. removed tree-length in bundles (FS crews cut & bundle); all standing and down dead timber 8'x3" (2.4 m x 7.6 cm) and larger removed if sound enough to yard.
GROUP SELECTION	All trees designated by utilization standard cut, in selected groups of 0.5 to 1.5 acres (0.2 to 0.6 ha) in size.	Same as (1), (2), and (3) above.
CLEARCUT	All trees designed by utilization standard cut.	Same as (1), (2), (3) above.

Six sale area blocks were logged, two under each basic silvicultural system. Each block was subdivided into treatment areas upon which the alternate levels of utilization were applied. Blocks were laid out to take advantage of existing and new system roads, and purposely included both up- and downhill yarding. Back-to-back yarding with the running skyline system allowed laying out the larger units up to 2,000 feet (609 m) in slope length. Utilization treatment areas designed for post-harvest broadcast burning were burned the season following logging.

Volumes of merchantable timber available for harvesting (table 2) ranged from 1,767 ft^3/acre (124 m^3/ha) in the conventionally logged shelterwood unit, to over 7,000 ft^3/acre (490 m^3/ha) in the group selection units. Volumes of nonmerchantable material included on intensively harvested units varied from 1,700 ft^3/acre (119 m^3/ha) to over 3,000 ft^3/acre (210 m^3/ha). Actual recovery of residue material, however, was generally no more than 25-50 percent of the gross volume potentially available. The remainder either did not meet the minimum size and condition specifications for removal, or was overlooked and left onsite.

Table 2.--Volumes of merchantable and nonmerchantable material available for harvest, and volumes of nonmerchantable material removed, under alternative treatment specifications, Coram site

Harvesting treatment	Volumes available for harvest				Nonmerch. volume removed
	Merchantable	Nonmerchantable			
		6"+ (15.2 cm)	3"-6" (7.6-15.2 cm)	<3" (7.6 cm)	
	- - - - - - - - - - - - -	- -	*Ft³/acre (m³/ha)*	- - - - - - - -	- - - - - -
Shelterwood:					
(1) Conventional	1,767 (124)	--	--	--	--
(2) Intermediate	2,299 (161)	734 (51)	966 (68)	--	425 (30)
(3) Intensive	2,057 (144)	813 (57)	918 (64)	48 (3)	906 (63)
Group Selection:					
(1) Conventional	7,083 (496)	--	--	--	--
(2) Intermediate	6,620 (463)	1,900 (133)	804 (56)	--	785 (55)
(3) Intensive	5,100 (357)	1,872 (131)	940 (66)	113 (8)	1,962 (137)
Clearcut:					
(1) Conventional	4,994 (349)	--	--	--	--
(2) Intermediate	5,520 (386)	2,408 (168)	631 (44)	--	860 (60)
(3) Intensive	3,515 (246)	1,702 (119)	530 (37)	23 (2)	783 (55)

Harvesting productivity and calculated costs of harvesting are described in table 3. The costs shown were developed on the basis of recorded production per hour and calculated system costs per hour. All turns yarded were scaled to determine the volumes of merchantable and nonmerchantable material produced per hour. Cost estimation was based on average industry costs (1974 dollars) for the equipment and crews being used.

Harvesting costs, such as the cost of a yarder and operating crew, can most conveniently be expressed per hour of operation. Other costs, such as the cost of felling and bucking timber, are commonly expressed per unit of volume produced. To develop a common base for combining costs, a "system cost per hour" was adopted. System cost per hour is comprised of the yarder and crew cost per hour, plus the costs of all other logging functions (fell, buck, bunch) required to produce the volume of material yarded in an hour. These costs can then be allocated against volume produced per hour in any desired fashion.

Table 3.--Harvesting productivity and calculated costs of harvesting, Coram site

Harvesting treatment	Yarder production/hour: Merchantable		Yarder production/hour: Nonmerch.	Cost of hourly production: Fell-buck-bunch: Merchantable	Cost of hourly production: Fell-buck-bunch: Nonmerch.	Cost of hourly production: Yarding	Total hourly cost	Cost per M bd. ft. merch.[1]	Cost per m^3, all volume
	Bd. ft.	*Ft*^{3} (*m*^{3})	*Ft*^{3} (*m*^{3})	- - - -	- - - -	Dollars (1974)	- - - -	- - - -	- - - -
Shelterwood:									
(1) Conventional	2,968	474 (13)	0 --	53	--	187	240	81	18
(2) Intermediate	2,355	379 (11)	114 (3)	56	17	187	260	110	19
(3) Intensive	1,267	204 (6)	488 (14)	31	91	187	309	237	15
Group Selection:									
(1) Conventional	3,276	524 (15)	0 --	59	--	187	246	75	16
(2) Intermediate	3,026	484 (14)	189 (5)	73	28	187	288	95	15
(3) Intensive	2,130	340 (10)	324 (9)	51	60	187	298	140	16
Clearcut:									
(1) Conventional	5,398	862 (24)	0 --	65	--	187	252	47	11
(2) Intermediate	4,654	745 (21)	134 (4)	74	13	187	274	59	11
(3) Intensive	3,138	506 (14)	100 (3)	50	15	187	252	80	15

[1]Total costs allocated to merchantable volume recovered.

Costs attributable to residue recovery (tables 4 and 5) can be calculated in either of two ways, depending upon the philosophy adopted. The first approach, illustrated in table 4, initially assigns all costs of harvesting to the merchantable saw log volume recovered (table 3). The differences in cost per M bd. ft. of merchantable volume between the conventional saw log units and the more intensively utilized units are ascribed to residue recovery (table 4). Example: Intermediate utilization under the shelterwood prescription results in a difference in cost per M bd. ft. of \$110-\$81 = \$29 (from table 3). This cost is assigned to residue recovery of 48 ft^3 per M bd. ft., resulting in a calculated residue recovery cost of \$29 ÷ 48 = \$0.60/ft^3 (table 4). The assumption is that costs of recovering merchantable material should not vary among the treatments; consequently, any change in cost must be attributable to recovering nonmerchantable material. Where residue recovery is required by contract, and in the absence of viable markets for residue material, this is likely to be the cost approximation method adopted.

Table 4.--Cost of residue recovery, allocating to residues all costs in excess of saw log harvesting costs experienced in conventionally logged units

Harvesting treatment	Residue volume recovered per M bd. ft. logged	Added cost of logging per M bd. ft.	Imputed cost of residue recovery		Cost per dry ton
			Per ft^3	Per m^3	
	Ft^3 (m^3)	*- - - - - - - Dollars (1974) - - - - - - - -*			
Shelterwood:					
(1) Intermediate	48 (1.4)	29	0.60	21	48
(2) Intensive	385 (10.9)	156	.41	14	33
Group Selection:					
(1) Intermediate	62 (1.8)	20	.32	11	26
(2) Intensive	152 (4.3)	65	.43	15	34
Clearcut:					
(1) Intermediate	29 (0.8)	12	.41	15	33
(2) Intensive	32 (0.9)	33	1.03	37	82

A second approach to estimating costs of recovering residue material, illustrated in table 5, allocates total harvesting costs to merchantable and nonmerchantable material. Felling, bucking, and bunching costs are identified separately for nonmerchantable material, and total yarding costs are prorated on the basis of cubic volume of each yarded. This would seem to be a preferred approach to calculating costs in situations where merchantable and residue material are being jointly harvested for identified end uses.

Table 5.--Cost of residue recovery, allocating costs to merchantable and nonmerchantable volumes recovered

Harvesting treatment	Residue volume recovered per production hour	Cost of felling, bunching[1]	Proportional cost of yarding[2]	Cost of residue recovery		Cost per dry ton
				Per ft^3	Per m^3	
	Ft^3 (m^3)	- - - - - -	- - - - - - *Dollars*	*(1974)* - - - - - -	- - - - - -	- - - - - -
Shelterwood:						
(1) Intermediate	114 (3.2)	17	43	0.53	19	42
(2) Intensive	488 (13.8)	91	132	.46	16	37
Group Selection:						
(1) Intermediate	189 (5.3)	28	53	.43	15	34
(2) Intensive	324 (9.2)	60	91	.47	16	38
Clearcut:						
(1) Intermediate	134 (3.8)	13	29	.31	11	25
(2) Intensive	100 (2.8)	15	31	.46	16	37

[1]Based on two-thirds of residue volume in trees requiring felling; one-third of residue volume in trees requiring felling and bunching.

[2]Yarding cost/hour prorated between merchantable and nonmerchantable material based on cubic volume of each yarded.

Tractor Skidding--The Lubrecht Site

The Lubrecht study site is located on Lubrecht Experimental Forest, a State-owned and administered area belonging to the University of Montana. The area is essentially dry site Douglas-fir, with a significant intermixture of ponderosa pine and western larch, on gentle terrain. The area has a cutting history of selective removal of older, larger timber in the late 1800's-early 1900's. The remaining mixed species and mixed age class stand is broadly representative of a major segment of the commercial forest land in the region. In addition, the stand occurs on one of the more productive Douglas-fir habitat types (*Pseudotsuga menziesii/Vaccinium caespitosum*), and represents an operating situation and management opportunity in which intensive utilization is likely to occur first. The mixed size and age classes provide an opportunity for a range of silvicultural and utilization options.

Harvesting treatments tested were developed to include combinations of silvicultural practices, utilization standards, and postharvest site treatments considered viable management options. Silvicultural prescriptions and utilization standards specified for the cutting units are described in table 6.

Table 6.--Harvesting treatment specifications for cutting, Lubrecht site

Silvicultural system	Cutting specifications	Utilization standards
CLEARCUT	Harvest all trees merchantable under the specified utilization standard.	Conventional utilization--removal of green and sound dead logs from sawtimber trees 9" (23 cm) and larger d.b.h.; utilization to 5" (13 cm) top, and one-third or more sound. Intensive utilization--removal of all green and dead saw log material if sound enough to skid; removal of all submerchantable trees 1" (2.5 cm) and larger in d.b.h., tree length (smaller stems hand bunched prior to skidding).
SELECTION	Harvest about half of the merchantable volume, leaving designated overstory of small sawtimber and pole stems. Dense sapling and pole stands selectively thinned.	Conventional utilization
UNDERSTORY REMOVAL	Harvest about half of merchantable volume (and up to two-thirds of total cubic volume), leaving designated overstory of better sawtimber and large poles.	Conventional utilization Intensive utilization
OVERSTORY REMOVAL	Harvest all sawtimber trees; thin pole stands, leaving seedling-sapling-small pole stems as residual stand.	Conventional utilization Intensive utilization

Four cutting units totaling approximately 60 acres (24 ha) were harvested, one under each of the described silvicultural prescriptions (fig. 2). The three units designated for clearcut, overstory removal, and understory removal were further subdivided into treatment areas for application of the two utilization standards. The remainder of this discussion will cover only the three harvesting treatments that included intensive utilization.

Figure 2.--Harvested units on the Lubrecht site included clearcut (left), and understory removal (right) treatments. Intensive utilization subunits are illustrated.

Gentle slopes and easy access to cutting units made possible the use of a ground skidding harvesting system. On all units logs were skidded with crawler tractors. On areas designed for intensive utilization, smaller trees (1" to 6" [2.5 to 15 cm] in diameter) were bunched by hand prior to skidding, and were skidded tree length.

Volumes of merchantable timber harvested from the units ranged from approximately 4 M bd. ft. (understory removal) to over 11 M bd. ft. (clearcut) (table 7). Volumes of nonmerchantable material recovered varied from 630 to 880 ft^3 per acre (44 to 62 m^3 per ha). Harvesting costs per acre and per unit of material recovered are shown in table 7.

The summary and analysis of harvesting productivity on this site is based upon documenting the volume and number of stems removed under each treatment specification, determining the crew and equipment time involved in each harvesting function, and relating time (and cost) to volume. Time and productivity data for the skidding operation were obtained by direct measurement of turn times and volumes or pieces moved. Sawyer time for felling and bucking was estimated from the contractor's records. Production rates for felling and bundling smaller stems under the intensive utilization option were derived from measured production per crew hour.

Typical industry costs (1977 dollars) for crew and equipment time were applied to derive cost per unit of volume produced. In the conventional utilization blocks, all costs were ascribed to the removal of merchantable logs. This base cost was also applied to the merchantable volume removed under intensive utilization, and the balance of harvesting costs incurred in these blocks was attributed to removing the nonmerchantable material.

Intensive utilization removes residue material that would otherwise typically require some residue reduction treatment (fig. 3). Slashing, or slashing followed by burning, are common treatments. Costs of residue recovery can be calculated either ignoring or recognizing the reduction in postharvest treatment costs, depending upon the rationale favored. Tables 8 and 9 demonstrate costs of residue recovery under both conditions. Gross costs of residue recovery, ignoring reductions in subsequent treatment costs, range from \$0.63 to \$0.80 per cubic foot (\$22-\$29/m^3) (table 8). Allowing credit for reduction in residue treatment costs (table 9) reduces the net costs of residue recovery to \$0.42 to \$0.75 per cubic foot (\$15-\$27/m^3).

Figure 3.--Residue reduction treatments following conventional saw log harvesting typically include slashing and burning.

Table 7.--Volume recovery and calculated costs of harvesting, Lubrecht site

Harvesting treatment	Volume recovery				Cost/acre, stump to deck			Total cost per acre	Cost per M bd. ft. merch.[1]	Cost per m^3, all volume
	Merchantable		Nonmerch.		Fell, buck	Bunch	Skid			
	M bd. ft./a	*(m^3/ha)*	*Ft^3/a*	*(m^3/ha)*	- - - - - - - - - - -	- *Dollars (1977)* -				- - - - - - - - - - - -
Understory removal:										
(1) Conventional	4.46	(51.9)	--		96	--	183	279	63	13
(2) Intensive	5.77	(67.2)	879	(61)	219	256	435	910	158	18
Overstory removal:										
(1) Conventional	8.80	(102.5)	--		196	--	367	563	64	14
(2) Intensive	8.85	(103.1)	632	(44)	253	200	513	966	109	16
Clearcut:										
(1) Conventional	11.59	(135.0)	--		195	--	380	575	50	11
(2) Intensive	10.66	(124.2)	732	(51)	310	176	633	1,119	105	16

[1]Total costs allocated to merchantable volume recovered.

Table 8.--Cost of residue recovery, assuming no credit for reduction in postharvest treatment costs, Lubrecht site

Harvesting treatment	Residue volume recovered per M bd. ft. logged	Added cost of logging per M bd. ft.	Imputed cost of residue recovery		Cost per dry ton
			Per ft^3	Per m^3	
	Ft^3 (m^3)	- - - - - - *Dollars (1977)* - - - - - -			
Understory removal:					
Intensive	152 (4.3)	95	0.63	22	50
Overstory removal:					
Intensive	71 (2.0)	45	.63	23	50
Clearcut:					
Intensive	69 (1.9)	55	.80	29	64

Table 9.--Cost of residue recovery, allowing credit for reduction in postharvest treatment costs, Lubrecht site

Harvesting treatment	Residue volume recovered per M bd. ft. logged	Added cost of logging per M bd. ft.	Less savings in slashing costs	Less savings in slashing and burning costs	Net cost per ft^3 (m^3) when treatment is		Net cost/ dry ton	
					Slash only	Slash/ burn	Slash only	Slash/ burn
	Ft^3 (m^3)	- - - - - - *Dollars (1977)* - - - - - -						
Understory removal:								
Intensive	152 (4.3)	95	77	64	0.51 (18)	0.42 (15)	41	34
Overstory removal:								
Intensive	71 (2.0)	45	40	34	.56 (20)	.48 (17)	45	38
Clearcut:								
Intensive	69 (1.9)	55	52	47	.75 (27)	.68 (25)	60	54

In-woods Chipping--The Teton Site

The Teton study site is located on the Gros Ventre District, Bridger-Teton National Forest, southwest of Dubois, Wyo. The site is typical of higher elevation old-growth lodgepole pine in the central and northern Rocky Mountains. The area is a gently rolling plateau at about 9,000 feet (2 743 m) elevation, in the *Abies lasiocarpa/Vaccinium scoparium* habitat type. The stands are essentially pure, overmature lodgepole pine, interspersed with natural, open meadows. Stand volumes are heavy for lodgepole pine, averaging in excess of 9,000 ft^3 per acre (254 m^3/ha) in stems 3 inches (7.6 cm) d.b.h. and larger. Standing and down dead material makes up approximately one-third of this volume.

Harvesting activity in old-growth lodgepole pine often results in large volumes of residue because of the decadent nature of the stands. Consequently, harvesting alternatives that can achieve more intensive recovery and utilization of the total fiber resource are particularly important to successful management of the site. Intensive utilization can solve a difficult residue disposal problem, reduce adverse public reaction to harvesting, and facilitate planting and other site-management activities.

Old-growth lodgepole pine is usually clearcut in some fashion because a manageable residual stand does not exist. Treatments applied to the study site specified clearcutting, and included two levels of utilization, described in table 10.

Table 10.--Harvesting treatment specifications for cutting units, Teton site

Silvicultural system	Cutting specifications	Utilization standards
CLEARCUT	All trees designated by utilization standard cut. On conventional utilization units, all green and recently dead merchantable sawtimber trees cut and bucked. On intensive utilization units, all trees (green and dead) 3" (7.6 cm) d.b.h. and larger cut with feller-buncher.	(1) Conventional: logs to 8'x6" (2.4 m x 15.2 cm) top, one-third or more sound, taken from all green and recently dead trees 9" (22.9 cm) d.b.h. and larger. (2) Intensive: in addition to saw log recovery, all nonmerchantable trees 3"+ (7.6 cm) d.b.h., all sound down material 6'+ (1.8 m), and all residues from sawtimber trees chipped in field with whole-tree chipper.

Four cutting units, each approximately 20 acres (8.1 ha), were harvested. Two were logged to conventional utilization standards, using common chain saw felling and bucking, and log-length saw log skidding. Residue volumes following harvesting on these units amounted to over 4,300 ft^3 per acre (121 m^3/ha). The two remaining units were logged to a near-complete utilization standard using a feller-buncher (fig. 4), tree-length skidding with rubber-tired grapple skidders, and segregating merchantable logs at the deck. All material not meeting minimum specifications for saw logs was chipped using a portable whole-tree chipper at the site (fig. 5).

Figure 4.--A feller-buncher was employed on the Teton site to fell and bunch whole trees on the intensive utilization units.

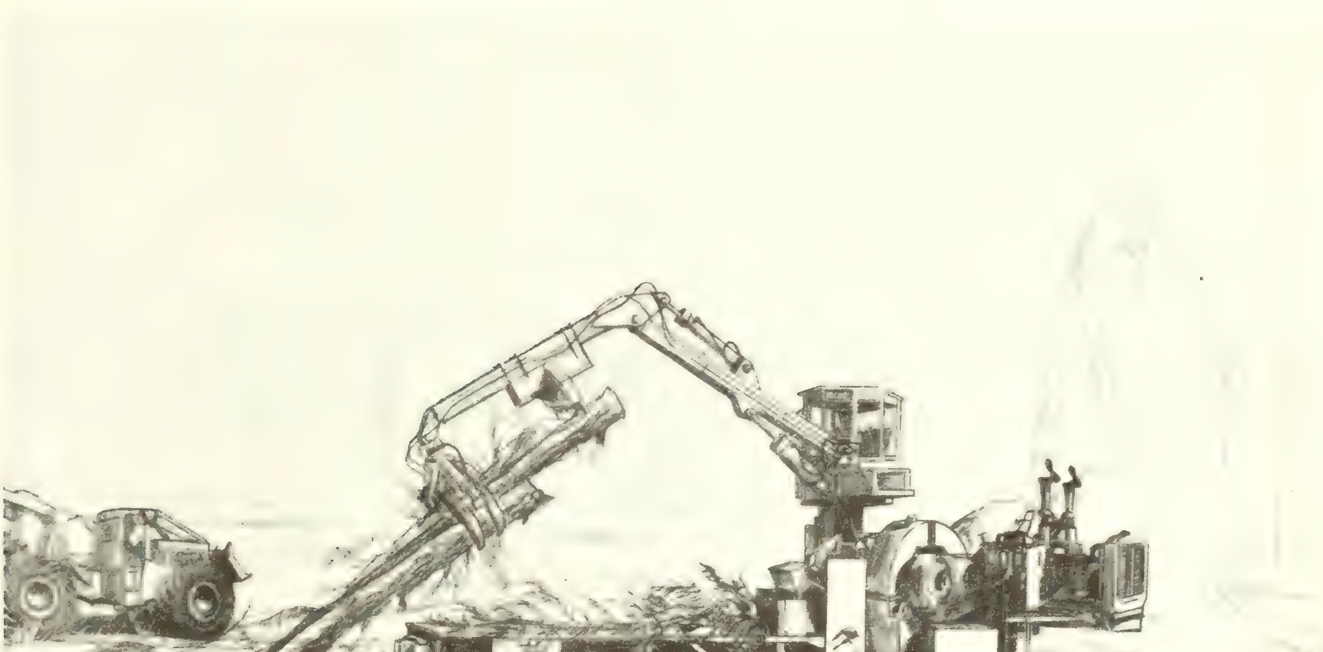

Figure 5.--All material not meeting minimum specifications for saw logs was chipped using a portable whole-tree chipper located on the logging site.

Gross volumes recovered from the cutting units included over 6,500 ft^3/acre (455 m^3/ha) of merchantable sawtimber, plus 4,580 ft^3/acre (320 m^3/ha) of nonmerchantable material from the intensive utilization units (table 11). Chip recovery was influenced by the utilization practices common at the time (1971). Only recently dead timber was considered merchantable for saw logs, and substantial volumes of standing sound dead timber were chipped. Under current utilization standards, much of this sound dead timber would be judged acceptable for sawn products.

Harvesting cost analyses for this site are based on documented crew and equipment time per unit of material harvested. Reported industry costs (1971) for crews and equipment were applied to derive costs per unit produced. Calculated costs, shown in table 11, indicate an average recovery cost of $0.14/$ft^3$ for harvesting nonmerchantable and residue material.

Table 11.--Volume recovery and calculated costs of harvesting, Teton site

Harvesting treatment	Volume recovery		Cost/unit, stump to deck				Cost per dry ton
			Merchantable		Nonmerch.[1]		
	Merchantable	Nonmerch.	Per M bd. ft.	Per m^3	Per ft^3	Per m^3	
	Ft^3/a (m^3/ha)	*Ft^3/a (m^3/ha)*	- - - - - - - - - - - - *Dollars (1971)* - - - - - - - - - - - -				
Clearcut:							
(1) Conventional	7,698 (538)	--	16	2	--	--	--
(2) Intensive	6,522 (456)	4,580 (320)	17	2	0.14	5	11

[1]Cost through chipper.

SUMMARY

The case studies reported here were conducted over a span of several years, as indicated. Consequently, the costs experienced in each case reflect the price level prevailing at the time, and cannot be directly compared. Table 12 summarizes costs of residue recovery for the three study operations, and adjusts costs to a common 1980 price base.

Caution must be exercised in drawing any conclusion from differences in costs between the case studies. Each study operation is unique in many respects--timber character, operating mode, crew skill and aggressiveness, and other factors. Costs cannot be assumed to represent more than the specific set of circumstances under which the case study was conducted.

Costs of residue recovery were generally sensitive to the volume of material recovered, with higher volumes per acre resulting in lower unit costs of recovery. The relatively low cost of residue recovery on the Teton site probably resulted from an extremely high volume of recoverable material per acre and the use of a harvesting system specifically designed for efficient residue recovery.

Present research efforts continue to be directed toward developing harvesting systems that can more efficiently recover material currently considered unmerchantable. A principal deterrent to improved recovery of residue material during logging operations is the cost of harvesting large numbers of small pieces, and subsequent handling and transportation problems. Systems that facilitate prebunching, whole-tree processing, and in-woods conversion to a form more easily handled and transported can improve the potential for utilization. Systems that can more efficiently operate in small-stem stands also afford the opportunity to recover such material before it is left as logging or thinning residue.

Better systems are also needed to accommodate the wide mix of material size and quality that may come from older, mixed stands. Most harvesting systems are best adapted to handling one or a few types of material, and additional classes of material are difficult to accommodate. Yet, an essential element in more complete and efficient utilization is the allocation of material to optimum end uses. Efficient harvesting systems for mixed material may require close coordination with merchandising or concentration yard processing and allocation operations, intermediate between the woods and the final processing plant.

Table 12.--Summary of costs of harvesting nonmerchantable material, and cost adjustment to 1980 price level

Study site	Harvesting treatment		Cost/unit, stump to deck: Study year price level, per ft³	1980 price level[4]: Per ft³	Per m³	Per dry ton
			Dollars			
Coram	Shelterwood					
	Intermediate	1	0.60	0.92	32	74
		2	.53	.82	29	66
	Intensive	1	.41	.63	22	50
		2	.46	.71	25	57
	Group Selection					
	Intermediate	1	.32	.49	17	39
		2	.43	.66	23	53
	Intensive	1	.43	.66	23	53
		2	.47	.72	25	58
	Clearcut					
	Intermediate	1	.41	.63	22	50
		2	.31	.48	17	38
	Intensive	1	1.03	1.59	56	127
		2	.46	.71	25	57
Lubrecht	Understory removal					
	Intensive	1	.63	.79	28	62
		3	.42	.53	19	42
	Overstory removal					
	Intensive	1	.63	.79	28	63
		3	.48	.60	21	48
	Clearcut					
	Intensive	1	.80	1.01	36	81
		3	.68	.86	30	69
Teton	Clearcut					
	Intensive		.14	.26	9	22

[1]Allocating to residue recovery all costs in excess of saw log harvesting costs experienced in conventionally logged units.

[2]Allocating costs between residue and merchantable volumes recovered, proportional to volume of material handled.

[3]Net cost of residue recovery, allowing credit for reduction in postharvest slashing and burning costs.

[4]Based on Gross National Product implicit price deflator (1972=base 100). Source: Dept. of Commerce, Bureau of Economic Analysis.

LOW CAPITAL INVESTMENT LOGGING SYSTEMS

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ABSTRACT

The selling price of logging equipment directly affects ownership costs, and indirectly affects operating costs. This paper shows that equipment selling price is not an indicator of machine productivity. Translated into machine production costs, which do not include any wages, supervision, or overhead, it cost 12 to 48 cents to skid each piece, with higher costs associated with higher priced skidders. Ten skidders were studied which included horse, farm tractor, track and rubber tired skidders.

Fifteen yarders were studied. The selling price of these machines ranged from $72,000 to $240,000. Yarding costs varied directly with selling price and ranged from $1.10 to $4.30 per piece and $5.77 to $23.90 per cunit.

KEYWORDS: capital productivity, logging production, logging costs, yarding, skidding.

INTRODUCTION

This report, part of a larger study of factors affecting the utilization of small trees, deals with the impact of capital investment on logging productivity and costs.[1]

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[1]The use of trade names does not constitute an official endorsement of or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

Generally, cost of capital refers to interest rates or capital stock marketing cost. But in the context of this report it refers to the production cost resulting from the cost of logging equipment. More specifically, this report discusses the machine cost of moving a tree, log, or piece of wood from the stump to a landing.

Two other terms have special meanings in the context of this report:

Skidding--refers to the process whereby a machine moves to a felled tree and drags the tree to a landing. Tractors can be used to skid logs or trees.

Yarding--refers to the process whereby a stationary machine, a yarder, sends out by cable a carriage or other device on which the felled trees or logs are attached. The trees or logs are then dragged or suspended to the landing by a process generally called line skidding. A jammer, line skidder, or yarder can all do the yarding function.

RESIDUE UTILIZATION LEVEL

Residue utilization involves a difficult set of conditions, including: 1) very low realization values, 2) cyclical or periodic markets, and 3) very high unit operating costs. The relationship between logging costs and residue utilization can be illustrated with a break-even approach to residue utilization levels.

Figure 1 shows the change in utilization level resulting from a change in logging cost. The solid curve represents normal logging cost with economic diameter limit at D and utilization level at M. A cost increase will shift to the lower dashed line, changing the economic diameter limit and utilization level to D_2 and M_2 respectively. The upper dashed curve shows the effect of a cost reduction; D shifts to D_3 and M shifts to M_3.

The significance of logging costs is clearly shown. Revenue represents the impact of realization values and markets.

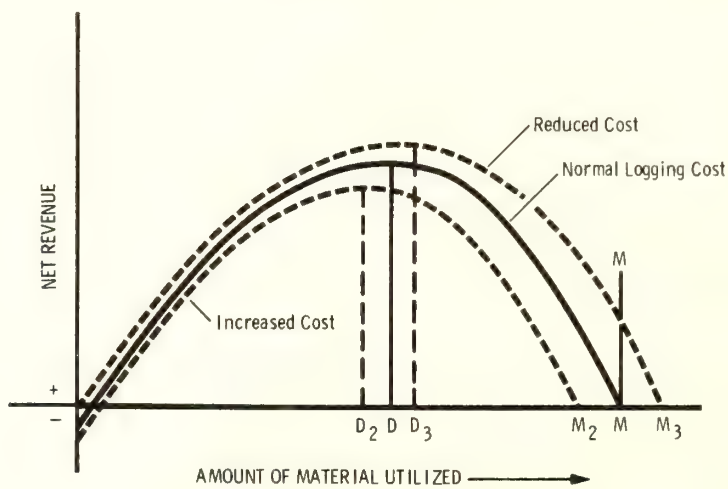

Figure 1.--Effect of logging cost on level of forest utilization.

Logging production costs are rising rapidly. It has been shown that sales realization changes directly affect stumpage rates (Host 1974); stumpage rates closely follow lumber prices. This suggests that revenues shown in figure 1 are relatively fixed or are beyond the control of the logger. Residue utilization levels, therefore, depend on logging costs, emphasizing the results illustrated in figure 1.

This paper will compare only the logging production costs of skidding and yarding. The choice between skidding and yarding is the most cost impacted decision in the logging system for it determines the feasibility of other parts of the total logging system.

SKIDDING PRODUCTION

Table 1 shows the observed production of 10 different skidding modes, including a horse. Machines 4 and 5 represent two different situations with the same farm tractor. Columns 8, 9, and 10 briefly describe the operating conditions; for example, column 10 shows the different travel speeds of loaded skidders on inhaul.

Because these observations were made over a period of years, all values have been adjusted to reflect summer 1979 price levels, shown in the adjusted price column. Where the original machine model has been discontinued (JD420, Garret 15 and AC180), a currently available comparable machine has been priced.[2] The last machine is a John Deere 540C with a grapple. This accounts for the drastic price difference from the other JD540's.

Horse skidding considers two horses, allowing one horse to rest while the other one skids small timber on steep ground.

Columns 4 and 6 show daily production in number of pieces (PCS) and cunits (CCF).[3] These are then divided by the adjusted purchase price (column 3) to produce the daily number of pieces and number of cunits per $100 of purchase price (columns 5 and 7). Cubic volume is used because the tree sizes are too small to measure in board feet. Also, the top volumes are included in these figures, which are gross scale volumes. There is not much defect in any of these volumes, except for the D2 machine study which had considerable material defect.

All the machines used chokers except the JD540-4 and AC180. Hence, number of pieces, trees, or logs is an important productive statistic. The table indicates the effect of grapples on number of pieces skidded per day, suggesting that added production rates compensate the added price of the grapple. This is shown in the upper set of curves in figure 2.

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[2]This paper's narrative and tables both abbreviate the names of specific equipment studied. Appendix A lists more detailed information about the machines.

[3]Gross cubic volumes are used to measure production rates. This was necessary because operating time on the landing did not allow for determining scaling defects and deductions. Cubic feet are used rather than board feet because most of these operations were in small timber which did not show board foot volumes. A cunit (CCF) equals 100 cubic feet.

Table 1.--Daily skidding production per $100 of purchase price.

	Machine model	Purchase price	Adjusted price	Pieces (PCS)	Daily Production PCS/$100	CCF[2]	CCF/$100	Vol/PC	Average Skid Distance		Average Skid Speed	
								ft³	ft.	m	ft/min	m/min
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)		(10)	
1	Horse[2]	3,000	3,800	114	3.0	5.6	.15	4.91	164	50	91	28
2	JD420[2]	900	6,500	112	1.7	5.0	0.10	4.96	260	79	76	23
3	D2[3]	600	10,000	104	1.0	12.2	0.12	11.73	70	21	78	24
4	AC180[4]	11,000	20,000	346	1.7	28.5	0.14	8.28	994	303	523	159
5	AC180[4]	11,000	20,000	224	1.1	37.9	0.19	16.88	801	244	356	109
6	G15[2]	2,500	22,000	168	0.8	7.9	0.04	4.70	254	77	102	31
7	JD540-1[4]	26,000	43,700	259	0.6	11.0	0.03	4.23	1,092	333	364	111
8	JD540-2[4]	29,000	43,700	304	0.7	32.0	0.07	10.53	1,125	343	357	109
9	JD540-3[5]	29,000	43,700	197	0.5	16.2	0.04	8.24	150	46	185	56
10	JD540-4[5]	38,000	60,700	368	1.0	42.7	0.07	11.60	300	91	117	36

[1]CCF = Cunit (100 cubic feet)

Production data source:

[2]Host, and Schlieter 1978.
[3]Chase 1979
[4]Host 1978
[5]Unpublished in-woods chipping study data.

See appendix for machine description.

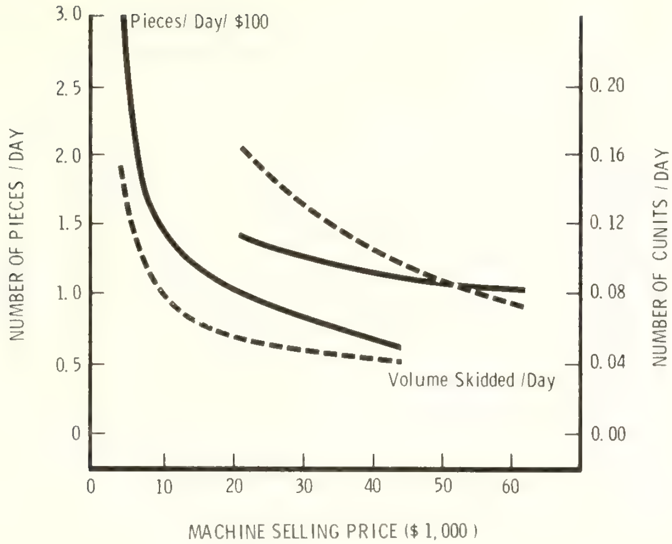

Figure 2.--Daily skidding production per $100 machine price--in cunits and number of pieces skidded.

Volume of material skidded per day is another important production statistic. Because this is greatly affected by individual average piece size, volume, in cubic feet, has been included in column 8. Relating these statistics to equipment selling price, it is obvious that skidding with horses is favorable in small timber. Figure 2 shows these statistics based on $100 selling price. Both statistics are included in the same figure in order to point out their similarity. This exclusion is made to point out that grapples represent a separate and unique skidding mode. Figure 2 shows that capital productivity decreases as more expensive skidding modes are used.

Skidding Production Costs

Table 2 shows the production costs for the units used in table 1 (pieces per day and volume per day in cunits). The table shows that total daily costs range from $22.98 to $109.82, with a mean of $56.32. There is a generally consistent increasing cost trend except for the Garrett 15. These costs might appear to be low, but these are machine costs and do not include any labor or overhead. (Figure 3 shows the daily machine costs for the skidders.) Columns 8, 9, and 10 are included to briefly describe the operating conditions. Figure 6 shows that the per cunit production cost increases only 7.1 cents per $1,000 selling price.

When looking at the cost to skid one piece, the trend is not as consistent as the total machine cost. Piece size has been included in table 2 because it might be thought to affect unit cost; but it does not appear to be a critical production variable. The larger sized timber does not have consistently higher costs per piece. Apparently, the same observation can be made when looking at cunit skidding costs. Figure 3 shows the daily machine cost as compared to machine selling price. The figure indicates that daily operating costs rise as the machines selling price rises.

Table 2.--Skidding production costs in dollars.[1]

Skidder	Daily Machine Cost			Unit Costs		Piece Size	
	Fixed	Variable	Total	Per Piece	Per CCF[2]	ft^3	M^3
Horse	3.12	19.86	22.98	0.20	4.10	4.91	.14
JD420	5.32	10.54	15.86	0.14	3.11	4.46	.13
D2	8.19	16.42	24.61	0.24	2.02	11.73	.33
AC180-1	16.38	25.08	41.46	0.12	1.45	8.28	.23
AC180-2	16.38	25.08	41.46	0.19	1.10	16.88	.48
G15	18.02	13.37	31.39	0.19	3.92	4.70	.13
JD540-1	35.80	55.70	91.50	0.35	8.32	4.23	.12
JD540-2	35.80	58.40	94.20	0.48	5.81	10.53	.30
JD540-3	35.80	61.20	97.80	0.32	3.03	8.26	.23
JD540-4	49.72	60.10	109.82	0.30	2.57	11.60	.33

[1]Costs do not include wages and overhead.
[2]CCF = Cunit (100 cubic feet).

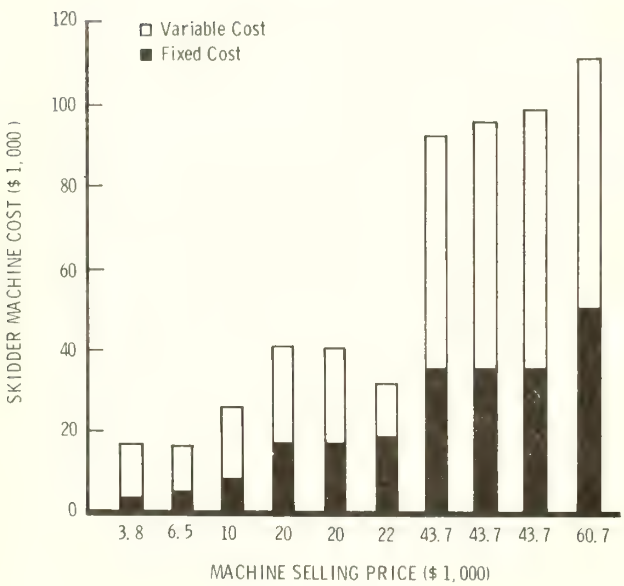

Figure 3.--Skidder machine cost versus selling price.

YARDING PRODUCTION

It is more difficult to compare yarding methods than skidding methods. Fixed costs become important in yarding, because the operation involves a relatively large portion of non-productive operating time during which the yarder is moved from one set to another. Production costs are greatly affected by piece size and volume cut per acre. Figure 1 showed that this affects economic diameter and volumes that can be utilized--a real dilemma.

Table 3 lists yarding production data for 15 different yarders one of which, the Ecologger I, was used in two different situations (nos. 6 and 7). It is important to point out that the production comparisons are based on $1,000 of machine price rather than $100, as in table 1. This transposition was necessary because of the high prices for yarders. As in table 1, columns 8, 9, and 10 have been included to briefly illustrate the conditions under which the machines were observed. Column 9 shows that the yarding distances did not vary as might be expected; that is, the difference between the average yarding distances for small and large machines was fairly small.

Neither were there differences as expected in line speeds (column 10). When determining line speeds, all inhaul delays were eliminated. A great deal of detail would be necessary to explain these. The impact of line speeds can be lessened considerably by other elements of the production cycle - chokersetting and lateral distances. Hence, they help to explain the production situation, but, often times, the significance of line speeds is over-emphasized.

Column 5 suggests there is no clear correlation between yarder price and number of pieces per day. However, there was an apparent drop after situation 10 (Link Belt 78-2). A trend in cunits per $1,000 (column 7) was even less apparent.

Figure 4 illustrates columns 5 and 7 of table 3. As with figure 2, the downward sloping line to the right indicates that the productivity of capital decreases as machine price increases.

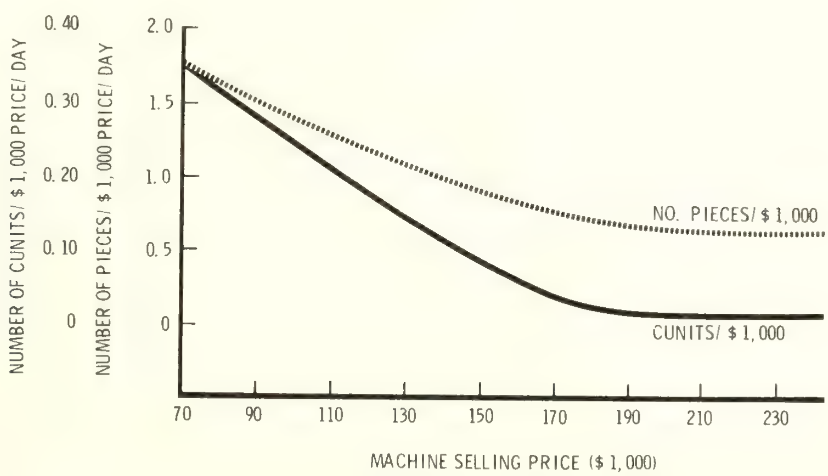

Figure 4.--Daily yarding production per $1000 machine price--in cunits and number of pieces yarded.

Table 3.--Yarding production data.

	Machine model	Purchase price	Adjusted price	Number pieces	DAILY PRODUCTION No. Pieces /$1000 selling price	DAILY PRODUCTION Cunits	DAILY PRODUCTION Cunits /$1000 selling price	DAILY PRODUCTION Piece vol ft^3	DAILY PRODUCTION Piece vol m^3	Average yarding distance ft.	Average yarding distance m	Inhaul speed ft/min	Inhaul speed m/min
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)		(9)		(10)	
1	U	49,000	72,000	110	1.53	24.81	0.34	22.55	.64	376	115	194	59
2	B-1	39,000	95,000	189	1.99	36.06	0.38	19.08	.54	104	32	73	22
3	B-2	39,000	95,000	73	0.77	14.69	0.15	20.10	.57	219	67	64	20
4	B-3	49,000	95,000	57	0.60	12.03	0.13	21.11	.60	155	47	50	15
5	22B	60,000	112,000	163	1.46	34.63	0.22	21.25	.60	156	47	106	32
6	E1-1	90,000	133,000	166	1.25	37.72	0.28	22.72	.64	250	76	397	121
7	E1-2	90,000	133,000	207	1.59	18.53	0.13	8.93	.25	291	89	416	127
8	LB78-1	120,000	136,500	222	1.63	33.30	0.24	15.00	.42	299	91	352	107
9	LB78-2	125,000	136,500	207	1.59	18.53	0.14	8.93	.25	221	67	326	99
10	LB98-1	105,000	180,000	87	0.48	15.66	0.09	18.01	.51	222	68	221	67
11	LB98-2	90,000	180,000	117	0.65	21.06	0.12	18.00	.51	144	44	61	19
12	C305	145,000	185,000	152	0.82	21.05	0.11	13.85	.39	197	60	152	46
13	LB108-1	155,000	210,000	145	0.69	26.43	0.13	18.23	.52	324	99	221	67
14	LB108-2	170,000	210,000	217	1.03	39.50	0.19	18.20	.52	302	92	249	76
15	W78	168,000	240,000	141	0.59	36.10	0.15	25.60	.72	378	115	269	82

Yarding Production Costs

Table 4 shows yarding production costs, and figure 5 shows the daily machine costs for the yarders. Total daily machine cost ranges from $178.39 to $506.38, with a mean of $322.46. Except for the two Link Belt 78's and the Koehring C305, the cost trend is consistently rising.

Table 4.--Yarding production costs, in dollars.[1]

	Daily machine cost			Unit cost		Piece Size	
Machine	Fixed	Variable	Total	Piece	CCF	ft^3	M^3
U	58.97	119.39	178.39	1.62	7.19	22.55	.64
B-1	77.81	130.15	207.96	1.10	5.77	19.08	.54
B-2	77.81	127.25	205.06	2.81	13.96	20.10	.57
B-3	77.81	123.56	201.37	3.53	16.74	21.11	.60
22B	91.73	160.22	251.95	1.55	7.28	21.25	.60
F210	106.48	195.52	302.00	1.68	7.39	22.70	.64
EI-1	108.93	247.80	356.73	2.15	9.46	22.72	.64
EI-2	108.93	215.08	324.01	1.57	17.49	8.93	.25
LB78-1	111.80	152.02	263.82	1.19	7.92	15.00	.42
LB78-2	111.80	186.56	298.36	1.44	8.62	8.93	.25
LB98-1	147.43	226.81	374.24	4.30	23.90	18.01	.51
LB98-2	147.43	266.52	413.95	3.54	19.66	18.00	.51
C305	151.52	248.61	400.13	2.63	19.01	13.85	.39
LB108-1	172.00	255.47	427.47	2.95	16.17	18.23	.52
LB108-2	172.00	275.59	447.59	2.06	11.33	18.20	.52
W78	196.57	309.81	506.38	3.59	14.03	25.60	.72

See appendix table for determination of machine costs, table 5.

[1]Labor and overhead costs are not included.

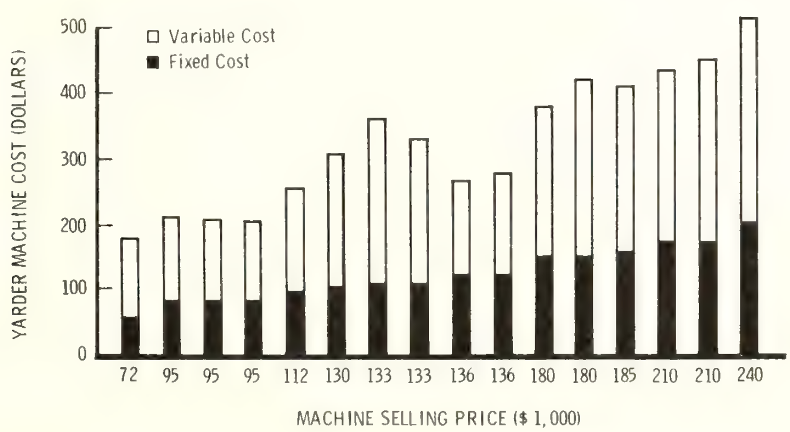

Figure 5.--Daily yarder machine cost versus selling price in dollars per day.

DISCUSSION

Many factors affect logging costs. This report considers only one of these factors in a sub-optimization context.

When evaluating capital productivity, one cannot be doctrinaire about purchase price impact on production cost. For instance, in some situations a $130,000 feller-buncher can be more economical than a $400 powersaw. It can be wrong to assume that smaller machines increase production efficiency in all cases. Efficiency is maximized when machines are properly matched to timber size and operating conditions within a total system. If it is valid to assume a decreasing capital productivity, why do some skidders and yarders sell for higher prices than others, and why would a smart logger buy a high-priced skidder or yarder? There are two different rationales explaining this phenomenon-- the "basic purchase function" and imposed logging constraints.

The "basic purchase function" has been described in detail elsewhere (Host 1978). Very briefly, it involves the assumption that higher priced machines have lower variable costs, so that the total cost is less for a high-priced than for a low-priced machine. The assumption is based on downtime and/or longer economic life.

Imposed logging constraints can be the overriding factor in machine purchase decisions. For instance, a long yarding distance requirement eliminates the possiblity of using many small yarders. This long line requirement has led to the demise of the "Idaho Jammer," the most efficient cable machine built. In addition, as has been shown, skidding is less costly than yarding; hence, when land management requirements exclude skidding, costlier yarders must be used.

This study documents that logging equipment prices directly affect logging costs. Followup analysis of downtime and delay causes would strengthen or weaken this documentation. At this time, it is apparent that machine size also affects logging costs.

The question of capital productivity also concerns the substitution of capital for labor. Labor shortages and an urgent need to keep production levels high can require large capital investments. In some cases, high production levels can reduce fixed cost impacts; for example, a small log operation would have low total costs, if it were transferring 3000 trees through the landing per 8 hour shift.

Figure 6 shows that the per cunit production cost increases only 7.1 cents per $1,000 of selling price. How does this slight cost increase, based on machinery price, translate to unit costs? The price ranges have a significant effect on residue utilization levels. Skidding unit costs range from 14 to 48 cents per piece and from $1.09 to $8.32 per cunit ($3.09 to $27.30 per cubic meter), with an average of 25 cents and $3.42, respectively. Yarding unit costs range from $1.10 to $4.30 per piece and from $7.19 to $23.90 per cunit ($23.59 to $78.41 per cubic meter), with a mean of $2.36 and $12.00, respectively.

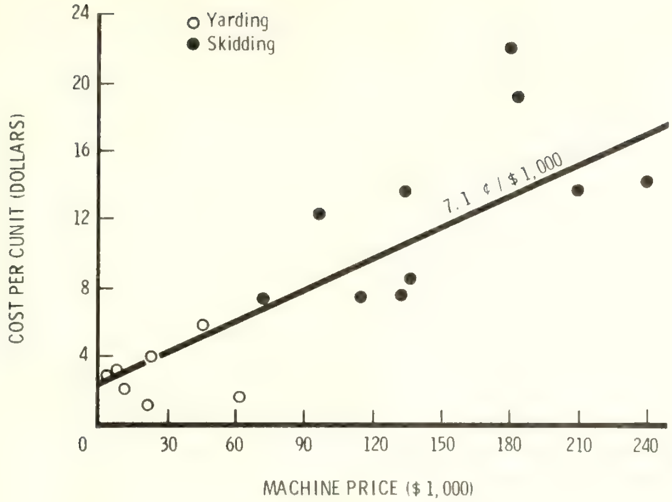

Figure 6.--Skidding and yarding production cost in dollars per cunit.

How does this affect utilization levels and resultant wood supplies? What would be the competitive advantage of substituting skidding for yarding in small timber and what is the net effect of capital equipment cost on residue utilization? These questions can be answered by a simple revision of figure 1.

In figure 1:

1. The solid line represents average logging machine price.

2. The upper dashed line represents skidders and the lower dashed line represents yarders.

3. Utilization levels will be improved by skidders where feasible. Or, instead of yarding utilized material, we should be skidding it. Or, utilization standards can be improved on skidding operations and slacked on yarding operations.

If we accept the conclusion that the costs of operating different machines vary in accordance with their different purchase prices, then any efficiency with size must come from labor productivity and supervision. That is, unit costs can be reduced by increasing daily production. This becomes increasingly critical when considering that skidders only need one person to operate them, whereas yarder crews consist of two to four persons. Some operating ratios show labor to total costs to be acceptable at 0.50 - 0.60. This means higher priced machines need much higher production rates.

Forest residues occur because they cannot be handled economically, so we need to reduce costs in order to utilize residues. But lighter cuts per acre and smaller timber increase costs and reduce values received. Where labor productivity is relatively constant, reduced logging costs will require consideration of other aspects. This suggests studying more productive ways to organize presently available technology. It also suggests studying and developing new logging technology.

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APPENDIX A

IDENTIFICATION OF LOGGING EQUIPMENT

Abbreviation	Machine
JD420	John Deere Model 420 tractor
D2	Caterpillar Model D2 (1958)
AC180	Allis Chalmers Model 180 farm tractor
G15	Garrett Tree Farmer Model 15
JD540-1, 2, 3	John Deere Skidder Model 540 C
JD540-4	John Deere Skidder Model 540 C Grapple
U	Urus 1000-3
B123	Koehring Bantam 3/8 yard converted shovel
22B	Bucyrus Eire 3/4 yard converted shovel
EI12	Ecologger I
LB7812	Link Belt Model 78 converted shovel
LB9812	Link Belt Model 98 converted shovel
C305	Koehring Model C305
LB10812	Link Belt Model 108 converted shovel
W78	Washington Yarder Model 78

APPENDIX B

Machine Cost Determination Assumptions

I. Fixed (Ownership) Cost

1. Straight line depreciation over 7 years at 1,500 hours per year.

$$\text{Depreciation per hour} = \frac{\text{Purchase price - Salvage value}}{\text{10,500 hours}}$$

   Salvage value very often depends on the bargaining position at the time of disposal, willingness of seller, market conditions, etc. Consequently, to be consistent, we assume there is no salvage value.

   For tax reasons one should use accelerated depreciation schedules. However, straight line depreciation is used on the assumption that the machines will wear out at a fairly constant rate over the 7 year life.

2. Average Annual Investment (AAI) is:

$$\text{AAI} = \frac{\text{Purchase Price - Salvage Value}}{\text{2 (Depreciation hours)}} - \frac{\text{Salvage Value}}{\text{Deprec. hours}}$$

$$= \frac{\text{Purchase Price}}{\text{2 (Depreciation hours)}} \quad \text{where salvage value is zero.}$$

3. Rate of interest is 15%. This is composed of the usual cost of money at 13% plus 2% for insurance and taxes.

4. Observations of these machines have been made over an extended period of time. In order to put these observations on a comparative basis, purchase prices have been updated to summer of 1979 price lists. Where some machine models have been discontinued, a comparable machine has been priced currently.

   Because fuel prices are so variable, the diesel fuel prices have been set at a constant price of $1 per gallon. This might appear high but it is an estimated price. As long as it is consistent, it does not favrr any one machine.

II. Variable (Operating) Cost

1. No labor or supervision costs have been included. They are irrelevant as far as the machine price comparisons are concerned.

2. Daily repair and maintenance costs will increase throughout the operating life of the machine. These will also vary considerably by operators for the same machine and the same working conditions. Generally, it can be assumed that the total repair and maintenance costs will equal the purchase price at the end of the operable (depreciable) life of the machine.

The repair and maintenance costs used herein correspond to the stage of the machine life at the time the observations were made. That is, these costs pertain to the time of observation but have been updated to August, 1979.

3. Skidder number 1 is a horse. This causes a unique costing situation whereby operating costs are determined on annual basis and then divided by 213 for a daily operating cost determination. This procedure is necessary in order to include the non-work period costs of food and care.

   The number of work days is determined as follows:

   Logging -- 183 days (Consisting of 131 work days plus 52 days on weekends during logging season)

   Ranch chores -- 30 days

   Horse

   Fuel = Feed--1 horse

7.40 months @ $110.00 =	$ 814.00	
4.60 months @ $ 75.00 =	345.00	
	$1159.00/horse/year	
	$2318.00/year =	$10.88/day
Shoes--51¢/day/horse =		1.02
Harness--$3.50/day/horse =		7.00
Vet service--$350.00/year/2 horses =		0.96
		$19.86/day/2 horses

Table 5.--Determination of yarder machine cost per day.

	Machine	Ownership Cost			Operating Cost				Total Cost	No. Pcs.	$/PC	Vol. CCF	$/CCF	$/m^3
		Depn	AAI x 15%	Total	Maint. Repair	Fuel & Lube	Rigging	Total						
1	U	54.86	4.11	58.97	78.46	7.00	33.96	119.42	178.39	110	1.62	24.81	7.19	23.59
2	B-1	72.38	5.43	77.81	63.35	22.00	44.80	130.15	207.96	189	1.10	36.06	5.77	18.93
3	B-2	72.38	5.43	77.81	72.59	18.00	36.66	127.25	205.06	73	2.81	14.69	13.96	45.80
4	B-3	72.38	5.43	77.81	74.98	16.00	32.58	123.56	201.37	57	3.53	12.03	16.74	54.92
5	22B	85.33	6.40	91.73	88.40	19.00	52.82	160.22	251.95	163	1.55	34.63	7.28	23.88
6	EI-1	101.33	7.60	108.93	141.08	44.00	62.72	247.80	356.73	166	2.15	37.72	9.46	31.04
7	EI-2	101.33	7.60	108.93	96.23	49.00	69.85	215.08	324.01	207	1.57	18.53	17.49	57.38
8	LB78	104.00	7.80	111.80	56.64	31.00	64.38	152.02	263.82	222	1.19	33.30	7.92	25.98
9	LB78	104.00	7.80	111.80	94.26	30.00	62.30	186.56	298.62	207	1.44	34.63	8.62	28.28
10	LB98	137.14	10.29	147.43	107.92	34.00	84.89	226.81	374.24	87	4.30	15.66	23.90	78.41
11	LB98	137.14	10.29	147.43	137.14	37.00	92.38	266.52	413.95	117	3.54	21.06	19.66	64.50
12	C305	140.95	10.57	151.52	124.36	37.00	87.25	248.61	400.13	152	2.63	21.05	19.01	62.37
13	LB108	160.00	12.00	172.00	110.43	46.00	99.04	255.47	427.47	145	2.95	26.43	16.17	53.05
14	LB108	160.00	12.00	172.00	114.78	51.00	109.81	275.59	447.59	217	2.06	39.50	11.33	37.17
15	W78	182.86	13.70	196.57	137.62	59.00	113.19	309.81	506.38	141	3.59	36.10	14.03	46.03

OUTLOOK FOR NEW HARVESTING TECHNOLOGY

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ABSTRACT

Because of increased emphasis on utilization of residues and smaller timber, rising energy and labor costs, and more severe environmental constraints pertaining to logging and road construction, the criteria for harvesting systems in the future will require both technological and institutional innovation.

This paper analyzes harvesting *per se* as well as its role in the total forest management picture. Models are presented for testing the sensitivity of total management cost and the harvesting components of cost to alternative silvicultural, utilization, and other forest management objectives. These models are used to discern opportunities for new harvesting technology.

KEYWORDS: logging systems, timber harvesting, forest management, cost modeling, new technology

INTRODUCTION

This paper analyzes some of the major factors that influence logging and total on-site forest management costs, and assesses the opportunities for future harvesting technologies in light of assumed forest management objectives and constraints. Our principal focus will be on the problems associated with mountainous terrain.

While there may be alternatives to truck hauling as the final stage in timber harvesting, it seems unlikely that such alternatives will be used in the next few decades--at least on a widespread basis. Therefore, our analysis assumes a continued need for roads and trucks.

Similarly, while wood fiber in any form may eventually be usable for whatever products society needs, it seems likely that leaving wood in its largest natural states will still be preferable for the foreseeable future. Therefore, our analysis excludes consideration of chipping at the stump or similar breakdown of trees between stump and roadside.

Finally, while we acknowledge the economic advantages of ground skidding with tractors--even in relatively steep terrain, we will pay little attention to such methods here. This is not to deny the widespread importance of such methods; rather, we assume that environmental and safety considerations will preclude their general applicability in much of our mountainous terrain.

In short, we confine our analysis to the matter of stump-to-mill transport and handling of trees, logs, and sensibly large pieces or aggregations of wood in mountainous terrain, with full recognition of the potentials for roadside chipping of certain residues to facilitate disposal or subsequent transport by trucks.

ANALYSIS OF CURRENT TECHNOLOGY

Traditionally, timber harvesting has been treated as a distinct activity, separate from the remainder of forest management activities, in spite of its recognized influence on the remainder of management. With minor exceptions, management of virgin forests before entry for harvest has traditionally been limited to control of fire, insects, and disease. Then, based largely upon the capabilities and limitations of harvesting technology, roads are located and constructed to the stands. After harvesting is completed, slash disposal, planting, and subsequent cultural treatments are undertaken until the stand is again ready for harvest. The point is that until stands become ready for initial harvest entry, management is largely passive. Moreover, the nature of management after harvest is largely influenced by the roads that are built for harvesting; and the locations and types of roads are influenced largely by the types of harvesting technology used.

Through a combination of economic and political processes, road densities have been decreasing and yarding or skidding distances have been increasing. Both road and harvesting costs have been rising, but the rising prices of wood products have generally permitted a continuation of traditional ways of doing business.

As the harvesting industry has complied with pressures to increase yarding distances and avoid undesirable environmental impacts, so have the Forest Service and other forest management agencies continued to push for more restrictions and more demanding and costly road construction and harvesting requirements. Rightly or wrongly, in recent years there has been a shift toward using the harvesting process to accomplish a wider range of forest management objectives.

Thus, even though we are concerned here with harvesting technology, it is necessary to consider the totality of forest land management--with harvesting as but one component of the total management scheme--and to examine the effects of new harvesting requirements and technologies on total management costs. To do this, we will construct a generalized model to portray total management costs per acre, including harvesting costs.

General Cost Model

Consider a tract of forested land that is to be roaded, harvested, and placed under active management. The principal cost components include road design, construction and maintenance, inventory and planning, harvesting and subsequent post-harvest slash disposal, planting, and other cultural treatments. It is assumed here that costs of surveillance and control of fire, insects, and disease are unrelated to the characteristics of road systems. Similarly, our model ignores the costs incurred by recreationists, grazers, and other forest users.

ROAD COSTS

Appendix A shows how per acre road costs (RC) are derived. In general, these costs can be expressed

$$RC = K_R \frac{C_R}{S} \tag{1}$$

where RC is in dollars per acre; C_R is the cost for design, construction and maintenance of roads expressed in dollars per mile; S is the average maximum yarding distance or span expressed in feet; and K_R is a coefficient reflecting the acres served by the roads and over which road costs are distributed. K_R is expressed in units of ft.-mile per acre.

Figure 1 illustrates the general form of per acre road costs (RC) as a function of average maximum yarding distance or span (S).

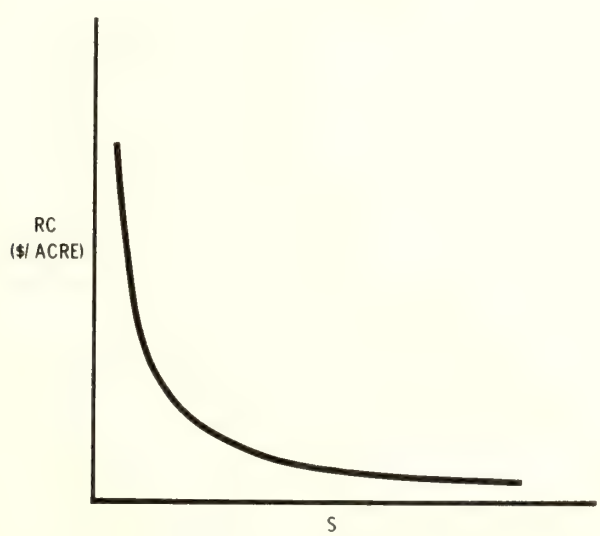

Figure 1.--General road cost (RC) versus span (S) relationship.

LABOR INTENSIVE COSTS

Appendix A contains a discussion of the types of pre- and post-harvest activities or treatments that are considered herein to be labor intensive, and for which the costs are affected by yarding distance or road spacing. The cumulative per acre costs (LIC) for such activities or treatments are derived in appendix A, and are shown to be

$$LIC = \sum_{i=1}^{m} \frac{C_i}{P_i T_i} \left(\frac{1}{1-K_i S}\right) \qquad (2)$$

where C_i is the daily cost for the i^{th} system; P_i is the basic production rate for the i^{th} system in acres per hour; and T_i is the available number of hours in the workday for the i^{th} system, exclusive of vehicle travel to and from the woods. S is as defined previously, and K_i is a coefficient reflecting walking speed between the roadside and work site, length of workday, and type of yarding system.

Figure 2 illustrates the general form of per acre labor intensive costs (LIC) as a function of average maximum yarding distance or span (S).

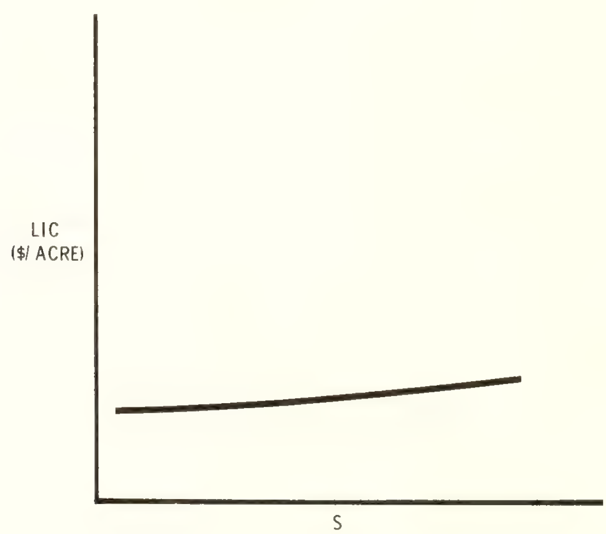

Figure 2.--Generalized relationship between labor intensive (LIC) and span (S).

LOGGING COSTS

It is convenient to consider logging as three separate operations: (1) falling (including in-woods processing); (2) yarding; and (3) hauling. Sometimes roadside processing, handling, and decking or loading accompany the yarding operation, in which case the definition of the yarding system would be broadened to include ancillary

labor and machinery. At other times, roadside processing, sorting and loading might accompany the hauling operation, in which case the definition of the hauling system would be broadened accordingly.

Appendix A shows the derivation of expressions for per acre falling costs (FC), yarding costs (YC) and hauling costs (HC). Respectively, these expressions are

$$FC = \frac{C_f\overline{V}}{P_f T_f}\left(\frac{1}{1-K_f S}\right) \tag{3}$$

$$YC = \frac{C_y}{60T_y}\left[\frac{43560}{b}\left(\frac{R_0}{S} + R_1\right) + \frac{(\overline{V} + V_R)}{v}\left(Y_0 + Y_1 S + Y_2 b + Y_3 n\right)\right] \tag{4}$$

and

$$HC = C_h\,(\overline{V} + V_R) \tag{5}$$

where C_f and C_y are the daily costs for the falling and yarding systems, respectively; $\overline{V}$ and V_R are the per acre volumes to be extracted of merchantable timber and residues, respectively; T_f and T_y are the available hours in the work day for the falling and yarding systems, respectively; P_f is the falling system production rate, in units of volume per hour; K_f is a coefficient reflecting walking speed between roadside and work site, length of workday, and type of yarding system; b is the average spacing between yarding corridors, in feet; v is the average volume per yarding cycle, expressed in units compatible with $\overline{V}$ and V_R; C_h is the hauling system cost per unit volume (where volume is expressed in units compatible with $\overline{V}$ and V_R; R_0 and R_1 are coefficients reflecting yarding system rigging time; Y_0, Y_1, Y_2 and Y_3 are coefficients reflecting yarding cycle time; n is the average number of pieces (or piece equivalents) per yarding cycle; and S is as previously defined.

Figure 3 illustrates the general form of FC, YC and HC as well as total logging cost (LC) versus S, where

$$LC = FC + YC + HC. \tag{6}$$

Note that there is an optimum span at which total logging cost is minimized, and beyond which per acre costs rise approximately at the rate at which per acre yarding costs increase.

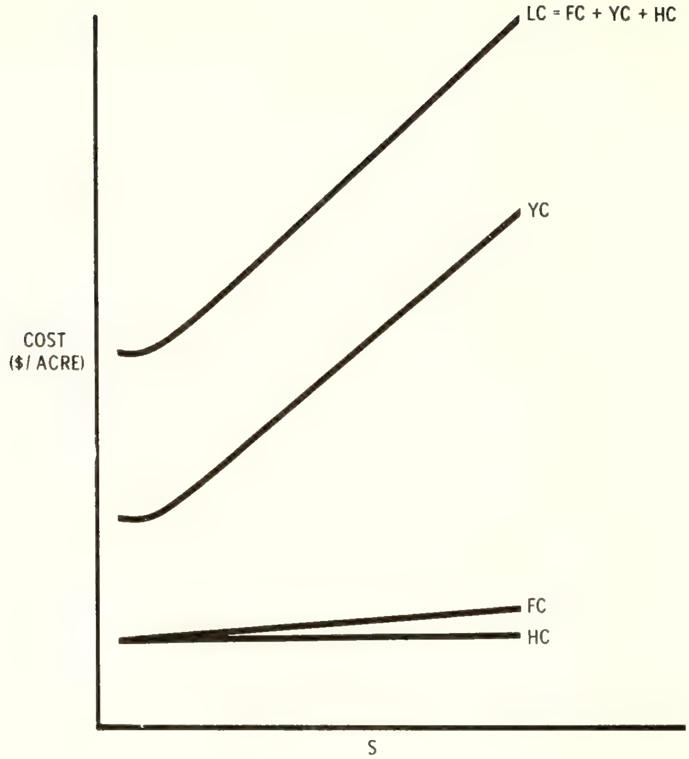

Figure 3.--General relationship between logging costs and span (S), where total logging cost (LC) is the sum of falling cost (FC), yarding cost (YC) and hauling cost (HC).

AGGREGATION OF COSTS

Assuming the period of consideration is sufficiently short that only one harvesting entry needs to be considered, and ignoring the time spread of investments during this period, then the total investment per acre (C) may be estimated as

$$C = RC + LIC + LC$$

or

$$C = K_R \frac{C_R}{S} + \sum_{i=1}^{m} \frac{C_i}{P_i T_i} \left(\frac{1}{1-K_i S}\right) + \frac{C_f \overline{V}}{P_f T_f} \left(\frac{1}{1-K_f S}\right)$$

$$+ \frac{C_y}{60T_y} \left[\frac{43560}{b} \left(\frac{R_0}{S} + R_1\right) + \frac{(\overline{V} + V_R)}{v} \left(Y_0 + Y_1 S + Y_2 b + Y_3 n\right)\right]$$

$$+ C_h (\overline{V} + V_R) \ . \qquad (7)$$

Use of equation 7 requires numerous assumptions relative to the stand and terrain conditions, the harvesting system to be used, and the nature of pre-and post-harvest activities. Our purpose here is to show how such a model can be used and to analyze the general effects of selected changes in conditions on per acre management cost.

First, we assume that management constraints do not preclude operation of the yarding systems at other than optimal corridor spacing. To determine this optimum, we differentiate equation 7 with respect to b and equate the resulting expression to zero to find

$$b_{opt} = \sqrt{\frac{43560\ (v)\ \left(\frac{R_0}{S} + R_1\right)}{Y_2\ (\bar{V} + V_R)}} \tag{8}$$

when we substitute equation 8 for b in equation 7, we obtain

$$C = K_R\ \frac{C_R}{S} + \sum_{i=1}^{m} \frac{C_i}{P_i T_i}\ \left(\frac{1}{1-K_i S}\right) + \frac{C_f \bar{V}}{P_f T_f}\ \left(\frac{1}{1-K_f S}\right)$$

$$+ \frac{C_y}{60T_y}\ \left[2\sqrt{\frac{43560\ Y_2\ (\bar{V} + V_R)\left(\frac{R_0}{S} + R_1\right)}{v}} + \frac{(\bar{V} + V_R)}{v}\ \left(Y_0 + Y_1 S + Y_3 n\right)\right]$$

$$+ C_h\ (\bar{V} + V_R) \tag{9}$$

Note that yarding cost is now

$$YC = \frac{C_y}{60T_y}\ \left[2\sqrt{\frac{43560\ Y_2\ (\bar{V} + V_R)\ \left(\frac{R_0}{S} + R_1\right)}{v}} + \frac{\bar{V} + V_R}{v}\ \left(Y_0 + Y_1 S + Y_3 n\right)\right] \tag{10}$$

Effects of Road Spacing or Span

Based on the example in appendix B, figure 4 illustrates the relationships of road costs, labor intensive costs, logging costs, and total managment costs versus span.

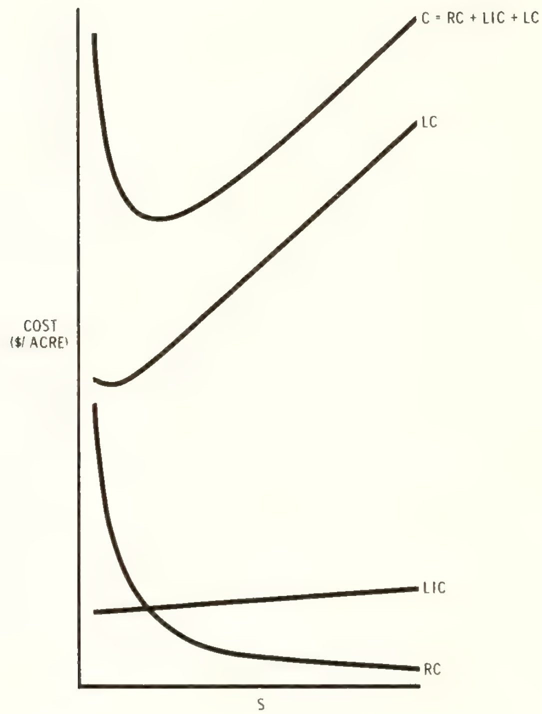

Figure 4.--General form of total management cost (C) versus span (S), where total management cost is the sum of road cost (RC), labor intensive cost (LIC) and logging cost (LC).

The major point to be made here is that the optimum span with respect to total management costs is significantly greater than the optimum span with respect to logging costs alone--nearly three-fold in this example, chiefly because of the influence of road costs.

A second point to be made from figure 4 is that, for spans greater than the optimum, the economic penalties increase at approximately the same rate as logging costs; as previously noted, logging cost increases are chiefly due to yarding cost increases.

The foregoing ignores any constraints on rigging, yarding, or road construction imposed by terrain or other factors. Indeed, as cable yarding distance is increased in mountainous terrain, multi-span capability often becomes necessary; and, correspondingly, rigging cost may rise dramatically. Obversely, as distances between roads increase, road costs per mile may decrease if road locations become less critical. Consequently, we believe that equations 7 and 9 above are generally both reasonable and useful with respect to a broad range of road spacings, even in difficult terrain.

Effects of Increasing Road Costs

Per acre road costs increase when per mile costs (C_R) increase or if the coefficient K_R increases. Figure 5 illustrates the effects of doubled per mile road costs on both per acre road costs and total management costs. The same effects would occur if per mile road costs remained unchanged and the acreage allocation coefficient K_A were to be halved. The implication of figure 5 is that as inflation or environmental constraints increase road costs, or as the proportions of accessed areas not managed or incapable of management increase, optimum yarding spans also increase. This implication alone makes increasing yarding distance capabilities a desirable goal for future logging technology.

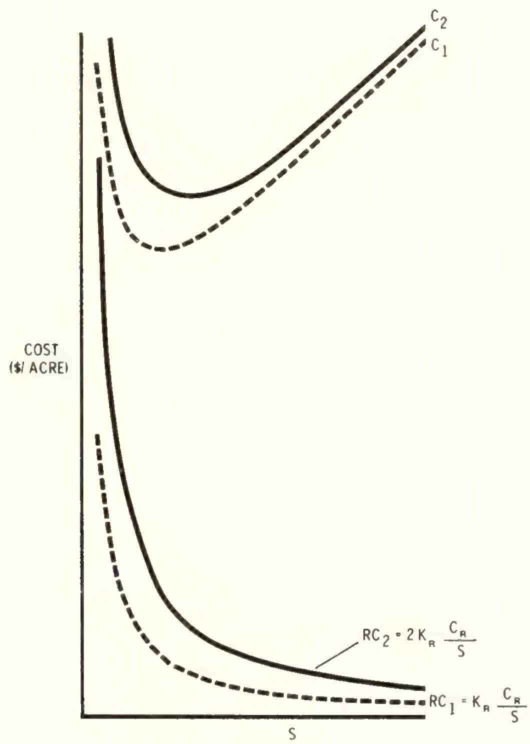

Figure 5.--Effect of doubled road cost on per acre road cost (RC) and total management cost (C) versus span (S). (RC_1 and C_1 represent the per acre road and total management cost of figure 4; and RC_2 and C_2 represent the per acre road and total management cost if per mile road costs are doubled.)

Effects of Reduced Cutting Intensity

If environmental considerations produce a preference for more selective logging and less clearcutting, the effect would be to reduce the extracted volumes per acre. With $\overline{V}_1$ representing the merchantable volume per acre to be removed on first entry into a stand, where

$$\overline{V}_1 = K\overline{V} \quad , \quad K < 1$$

(and $\overline{V}$, as before, is the total merchantable volume per acre in the stand), figure 6 shows the effect of selective logging on total per acre management cost and on cost per unit of merchantable volume removed versus span, S. (Figure 6 is based on calculations in appendix C, wherein K = 0.5.)

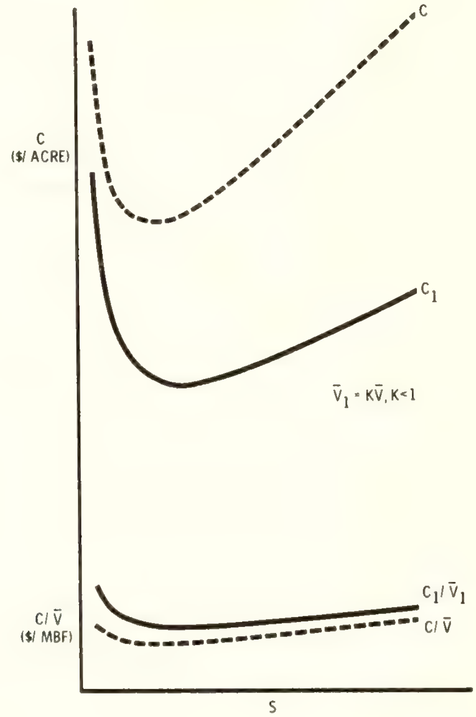

Figure 6.--Effect of partial cutting on total management costs per acre (C) and per unit volume ($C/\overline{V}$) versus span (S). (C and $C/\overline{V}$ correspond to figure 4; C and $C_1/\overline{V}_1$ correspond to the example of appendix C.)

Figure 6 shows that optimum spans are increased, based on total management costs incurred on first entry alone, and that economic penalties for increasing spans beyond the optimum are reduced in comparison with removal of the entire merchantable volume, $\overline{V}$. Of course, costs per unit volume also are increased, as shown in the bottom part of figure 6. Therefore, we conclude that selective logging increases the need for or the desirability of extended yarding spans and wider road spacings, at least on the basis of initial entry considerations alone.

If the economic planning horizon extends to later entries, however, then optimum spans would not be appreciably different from what they would be if all the merchantable volume were removed on first entry (fig. 7). That is, assuming the costs incurred on second entry are the same as those incurred on first entry (except for road costs), the sum of first and second entry per acre costs ($C_1 + C_2$) versus span, S, will be of about the same form as the C vs. S relationship shown in figure 4, although higher. Correspondingly, the total cost per unit volume will also be higher, or

$$\frac{C_1 + C_2}{\overline{V}} > \frac{C}{\overline{V}}$$

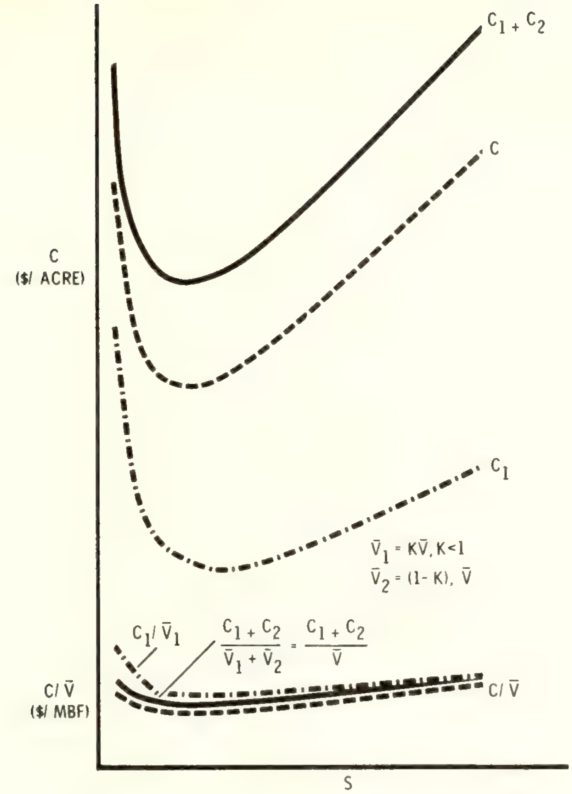

Figure 7.--Cumulative first and second entry management cost per acre ($(C_1 + C_2)$ and per unit volume $((C_1 + C_2)/\bar{V})$ versus span (S). (C, $C/\bar{V}$, C and $C/\bar{V}$ are from figure 5; C_2 and $\bar{V}_2$ are the additional costs incurred and volumes removed per acre, respectively, during second entry.)

Thus, based on considering all entries, from initial selective removal to final harvest cutting, there would appear to be no need for increasing yarding span capabilities; rather, the principal objective for new harvesting technology would appear to be a combination of lower costs and lower economic penalties for yarding beyond optimum spans.

Effects of Residues Removal

One may consider two basic classes of logging residues: (1) those that are similar in character to the merchantable logs (i.e., of comparable weight, length, and diameter), and (2) those that are small or irregular (e.g., limbs, tops, broken chunks, and small trees). The effect on cost of removing residues of the first type is not appreciably different from that of increasing per acre volumes to be removed. The upper part of figure 8 illustrates that total per acre management costs are increased, and that optimum spans are decreased, as per acre volumes of the first class of residues to be removed increase. (Figure 8 is based on data generated in appendix D.)

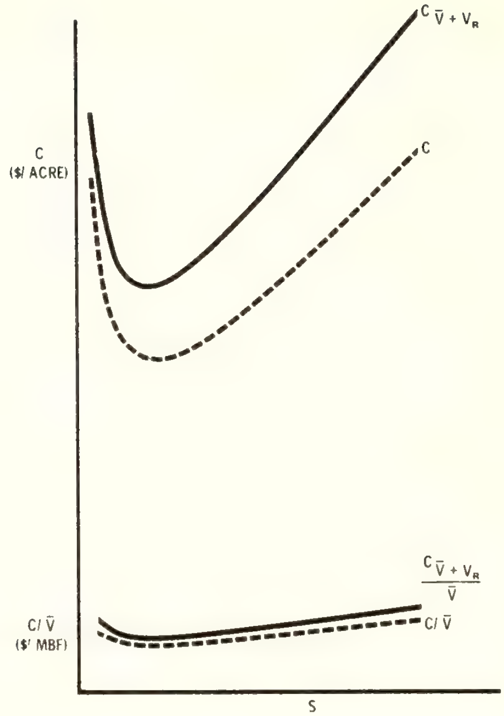

Figure 8.--Effect of residue removal on per acre management cost ($C_{\overline{V}} + \overline{V}_R$) and cost per unit of merchantable volume ($C_{\overline{V}+V_R}/\overline{V}$) versus span (S). (C and $C/\overline{V}$ are from figure 4.)

The lower part of figure 8 shows the effects of residue removal on cost per unit of merchantable volume; as would be expected, costs per unit volume in this situation are higher than for the case where $V_R = 0$.

If by removing the larger class of residues there would be no reduction in need for slash disposal or other labor intensive work (as was assumed in appendix D), then it would be of interest to determine what value these residues would need to possess in order to produce no economic penalty for their removal. If ρV_R were to represent the equivalent net merchantable volume in the residues, where $0 \leq \rho \leq 1$, then avoiding economic penalty would require that

$$\frac{C_{\overline{V}+V_R}}{\overline{V}+\rho V_R} \leq \frac{C}{\overline{V}}$$

or that

$$\rho \geq \frac{\overline{V}}{V_R}\left(\frac{C_{\overline{V}+V_R}}{C} - 1\right) \tag{11}$$

where $C_{\overline{V}+V_R}$ is the total per acre management cost incurred when both merchantable timber and residues are removed. (C, as before, would represent the total per acre management cost incurred when only merchantable timber is removed.)

Figure 9 (again based on an example outlined in appendix D) illustrates the relationship between ρ and S, and shows that the net merchantable volume (or equivalent thereof) must increase as yarding distances or road spacings increase.

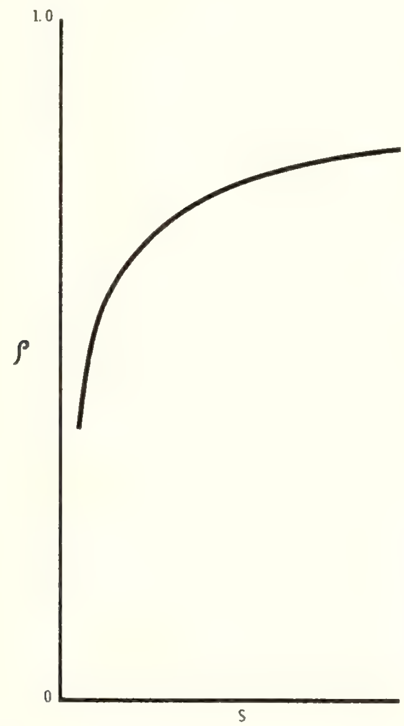

Figure 9.--Minimum net merchantability of residues (ρ) versus span (S) to avoid economic penalty for removal. (ρV_R is that function of gross residues volume, V_R, that is equivalent in value to the merchantable volume $\bar{V}$.)

Obviously, for residues of the second class (i.e., those containing no merchantable volumes), there can be no economic justification for removal except insofar as other on-site treatment costs can be reduced.

INTERIM CONCLUSIONS

It seems clear from the foregoing that if road costs continue to increase and selective logging is prescribed with greater frequency, then road spacings and yarding distance capabilities will likewise be required to increase if economic penalties for

operating below optimum spans are to be avoided. Correspondingly, the outlook for greater utilization of residues would be discouraging unless major reductions in yarding cost can be achieved.

As major goals for future harvesting technology, we see the following:

(1) Reduce total per acre management cost by providing the capability to yard at or beyond optimum spans.

(2) Reduce economic penalties associated with yarding distances or road spacings greater than the optimum.

We conclude that improved logging systems would offer the greatest opportunities for meeting these goals. In particular, yarding or stump-to-roadside operations would require the most improvement.

ANALYSIS OF PROSPECTS

We will now examine some possibilities for improving the stump-to-roadside transport situation. Our analysis assumes that little can be done to alter or reduce the cost of timber falling in steep terrain, at least in the near future, and that current labor intensive falling methods will continue indefinitely. The major opportunities for reducing the difficulties and costs of falling appear to be in reducing or eliminating the need for limbing and bucking in the woods through whole tree extraction and roadside processing.

We will consider opportunities for technological innovation in three areas:

(1) Aerial systems

(2) Cable yarding systems

(3) Combination yarding and forwarding systems

Aerial Systems

Three classes of aerial systems are analyzed in appendix E: (1) "small" helicopters, (2) "large" helicopters, and (3) "giant" airships. Based on these analyses, figure 10 shows an apparent potential for larger capacity helicopters or airships to achieve the desired goals of lower costs and reduced economic penalties for operating beyond optimum road spacings. However, as shown in the bottom portion of the figure, this potential can only be realized when production rates are in the order of 25 to 50 times those of "conventional" technology. Unless we can solve the logistical problems associated with falling and concentrating loads of logs or stems at rates sufficient to match the yarding production capacity of large aerial systems, it seems unlikely that the potential cost savings shown in figure 10 will be realized.

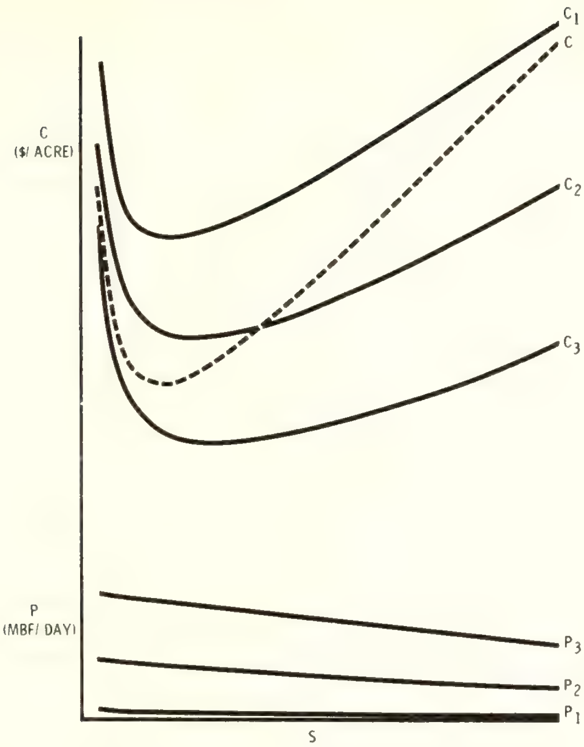

Figure 10.--Total per acre management costs (C) and daily production rates (P) versus span (S) with three classes of aerial systems. (C and P represent small helicopters, C_2 and P_2 represent large helicopters, C_3 and P_3 represent giant airships, and C is from figure 4.)

Cable Yarding Systems

With cable yarding systems, it would seem that opportunities for meeting our improvement objectives would be as follows:

(1) Increase load capacity

(2) Increase speed

(3) Reduce system cost

Increasing load capacity implies increasing either cable tensions or deflections. Given the prospects for harvesting smaller timber in the future, the difficulties associated with anchoring to resist higher cable tensions must be carefully considered. Increasing cable deflections--either through use of intermediate supports or by extending spans to take advantage of mountainous topography would be more likely to be acceptable.

Increasing the load capacity of yarding systems is likely to require some type of pre-bunching or load concentration in advance of or in conjunction with yarding, especially if selective logging of smaller timber is to be a common practice in the future. Simultaneously, pre-bunching should permit a reduction in yarding system labor requirements, assuming that pre-bunching is done in such fashion as to eliminate or reduce the need for pre-setting chokers.

Finally, it may be reasonable to assume that carriage speeds could be increased without appreciable increases in yarding equipment costs.

Appendix F contains an analysis based on a set of assumptions regarding all three of the above improvement objectives, and figure 11 illustrates the results of this analysis. As emphasized in appendix F, the assumptions used in developing figure 11 are exceedingly optimistic. Nevertheless, there appear to be significant opportunities for improving both conventional cable yarding systems and the procedures by which they are used, to reduce both total management costs and economic penalties for operation beyond optimum spans.

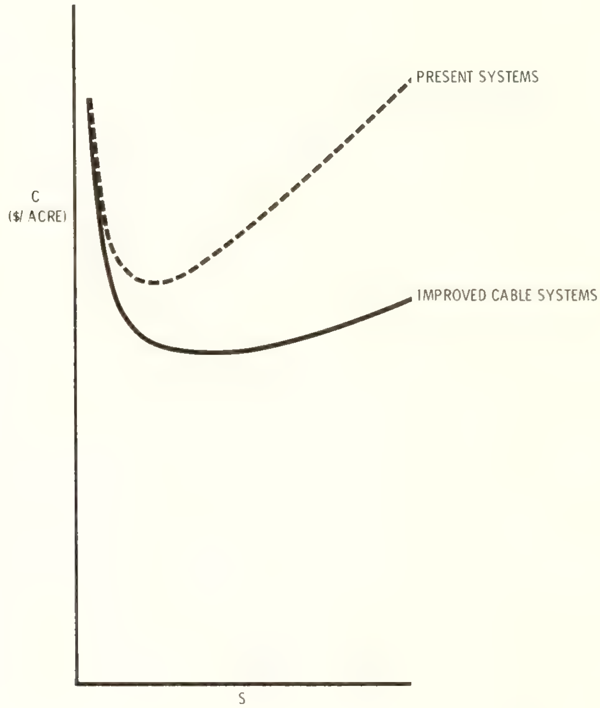

Figure 11.--Potential effect of cable systems improvements on total management cost (C) versus span (S). (Curve labeled "present systems" is from figure 4.)

Combination Yarding and Forwarding Systems

From the foregoing analyses, we realize that when using relatively high road densities (or relatively short yarding distances), road costs have a dominant influence on total management costs per acre. In contrast, at relatively low road densities (or relatively long yarding distances), road costs per acre become relatively minor, while yarding production costs exert the dominating influence on total management cost.

This suggests that, if we could (1) provide relatively inexpensive access for on-site-work--including timber falling and yarding of stems and logs, and (2) transport inexpensively large loads of stems and logs over relatively long distances, we might realize significant improvements both economically and environmentally.

Recently, attention has focused on giant airships to fulfill the latter objective, but little attention has been given to the former objective. Moreover, the sizes of airships being proposed are such that their economic feasibility depends on large quantities of available timber--so large that coordination among numerous logging

operations or between logging operations and other transportation tasks may be necessary to justify operation. There are both institutional and natural limits on the scale of technology, and some proposed airships may exceed these limits.

What, then, might we envision as an alternative to airships that would fulfill our objective of low cost, relatively long distance "roadless" transport without commensurate institutional problems and large energy requirements?

The situation represented in figure 12, where a system of "trails" spaced nominally at 10 percent of the road spacing, presents a potential solution. Appendix G analyzes the possibilities of this situation, in which some yet undeveloped yarding, forwarding and personnel transport technologies are assumed. Figure 13 illustrates the potential effects of such technologies on total management cost in comparison with present circumstances and with the optimistic cable yarding possibilities discussed previously.

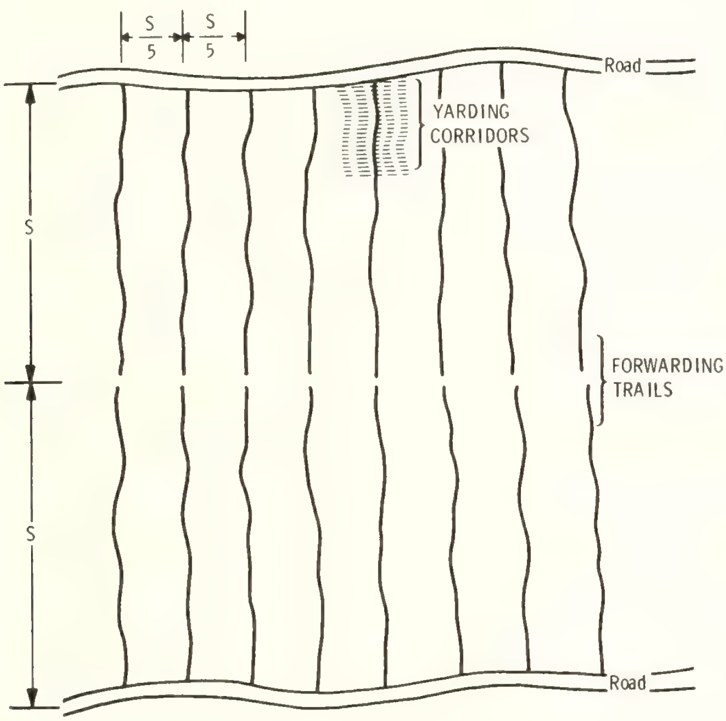

Figure 12.--Layout of roads, forwarding trails, and yarding corridors for hypothetical new yarding-forwarding systems.

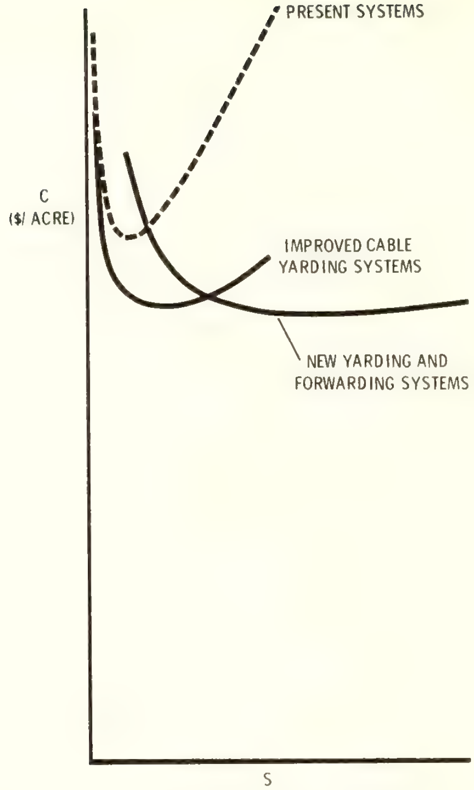

Figure 13.--Potential effects of technological improvements on total management cost (C) versus span (S). (Curves labeled "present systems" and "improved cable yarding systems" are from figure 11.)

SUMMARY AND CONCLUSIONS

As economic and environmental constraints become more severe, as timber sizes decline, and as more of the timber supply is derived from steep, difficult terrain, the prospects grow bleaker for new harvesting technology that will significantly reduce the costs of logging and total forest management. We can envision concepts that would appear to reduce the economic penalties of forest management in adverse circumstances, but it is unlikely that significant cost reductions will occur in the future.

Given the greater opportunities for logging mechanization in gentle terrain, it is virtually certain that management of steep terrain will always be economically disadvantageous. Nevertheless, timber in mountainous terrain is a resource that presumably will be needed. Therefore, there is strong justification for seeking less costly alternatives for extracting and replacing this resource.

Recognizing the risks, obstacles, and costs inherent in the development of radically new technology, it seems prudent first to seek improvements through "small" changes in existing technology and procedures. Given the likelihood of increasing

labor, energy, and road construction costs, greater restrictions on road location in difficult terrain, and the likelihood of more intense utilization and more partial or selective logging, the following approaches seem to offer moderate changes for cost reductions or improved operability:

(1) Extension of cable yarding distance capabilities

(2) Increasing the transport speeds of cable yarding systems

(3) Pre-bunching on site in combination with falling operations

Of course, increasing the load carrying capabilities of yarding systems also would theoretically lower costs; but it must be recognized that increasing load capabilities creates greater anchoring problems and/or the need for intermediate skyline supports. Moreover, greater difficulties are encountered in assembling larger loads as timber sizes decline.

The prospects for aerial yarding systems, such as helicopters and airships, are theoretically good, but the difficulties in providing sufficient timber to utilize their capabilities must be recognized and dealt with.

The prospects of a radically new, "trail-based" yarding and forwarding technology are appealing from both economic and environmental standpoints, and such a technology would seem almost as universally applicable as aerial systems. However, a gigantic effort would be required for development of such technology in a short period of time.

Although we have not dealt with the issue of in-woods processing, we suspect there are numerous opportunities for adoption or development of new handling, sorting, processing, and truck loading technologies. Indeed, there may be promising alternatives to conventional trucks for transporting wood products from forest landings to manufacturing facilities.

Finally, and perhaps most important, it must be recognized that minimizing logging costs may not--and probably will not--minimize total on-site forest management costs. In addition, depending on the transportation and harvesting technologies applied, the economic penalties for extending yarding distances beyond economic optima may be acceptable. Thus, while the economic justifications for modifying or developing harvesting technologies may be weak, there may be strong environmental and political reasons for doing so.

APPENDIX A

General Cost Model Derivations

ROAD COSTS

If the average distance between roads (road spacing) is $K_S S$ (where S is the average maximum yarding distance or span, in feet, and K_S is a coefficient reflecting whether the yarding system can yard in one or both directions to the road system), then the average total acreage accessed by each mile of road will be

$$\frac{5280\ (K_S S)}{43560} \simeq 0.121\ (K_S S)$$

If only a fraction (say, K_A) of the acreage accessed by the road system will be harvested or otherwise considered appropriate for road cost allocation, then the average acreage over which costs for each mile of road will be distributed is

$$0.121 K_A K_S S$$

Therefore, if road costs are C_R dollars per mile, road costs per acre served (RC) will be

$$RC = \frac{C_R}{0.121 K_A K_S S} = K_R \frac{C_R}{S} \quad ,$$

where $K_R = \frac{1}{0.121 K_A K_S}$

For example, if the yarding system can yard both uphill and downhill over average spans of S (feet), then K_S = 2 and average road spacing would be $K_S S$ = 2S (feet); and if road costs were to be allocated over the entirety of the acreage accessed, then K_A = 1. Accordingly,

$$K_R = \frac{1}{0.121(1)(2)} = 4.125 \text{ ft-mi/acre}$$

and

$$RC = 4.125 \frac{C_R}{S}$$

Alternatively, if the yarding system could yard only in an uphill direction to the road, then K_S = 1; and, if K_A = 1, then K_R = 8.25. But if only half the total acreage accessed by a road system contains resources that would justify the roads, then K_A = 0.5; and if K_S = 1, then K_R = 16.5 ft-mi/acre.

LABOR INTENSIVE COSTS

There are many reconnaissance, inventory, and planning activities that occur before roads are constructed, involving both aerial and on-site methods. These will be ignored in this derivation and considered to be a part of general forest management cost, similar to cost of fire surveillance. However, once roads are in place, the costs for on-the-ground cruising, timber marking, boundary surveying, slash disposal, planting and other activities before and after harvesting are affected by road spacing. We recognize that the cost per acre for some of these activities, such as unit boundary surveying and marking or fire line construction, are dependent upon the sizes and shapes of the harvest units. Nevertheless, we will ignore relationships between unit perimeters and unit areas in this development. Basically, we need consider only the production rate for on-site activities and the distance from site to road.

In any workday, the hours spent by a worker in walking to and from the work site may be expressed as

$$2\left(\frac{1}{2}\right)\left(\frac{K_S S}{2}\right)\left(\frac{1}{V_w}\right) = \frac{K_S S}{2V_w}$$

where $K_S S/2$ is the average maximum distance, in feet, from roadside to the work site; and V_w is the average walking speed, in feet per hour. If the total available time in a workday is T hours (exclusive of time spent in vehicle travel at the beginning and end of the workday) then the average net time available for work on site is

$$T - \frac{K_S S}{2V_w} = T\left(1 - \frac{K_S S}{2TV_w}\right) .$$

If the hourly production rate for the i^{th} labor intensive activity is P_i, in acres/hour, then the acres treated per workday will be, on the average,

$$P_i T_i \left(1 - \frac{K_S S}{2T_i V_w}\right) ,$$

and the cost per acre treated will be

$$\frac{C_i}{P_i T_i}\left(\frac{1}{1 - \frac{K_S S}{2T_i V_w}}\right)$$

where C_i is the daily cost for labor, equipment, travel, and administration corresponding to the hourly production rate of P_i, and T_i is the available working hours in the workday for the i^{th} system.

Therefore, letting

$$K_i = \frac{K_S}{2T_i V_w} ,$$

the total of all labor intensive costs will be

$$LIC = \sum_{i=1}^{m} \frac{C_i}{P_i T_i} \left(\frac{1}{1 - K_i S} \right)$$

where m is the total number of discrete pre-and post-harvest labor intensive activities or treatments to be conducted, and LIC is expressed in dollars per acre so treated.

As an example, suppose the i^{th} activity is lopping and scattering of slash after logging, and the i^{th} system is a worker and chainsaw. Suppose C_i is \$100 per day, P_i is 0.1 acre per hour, and T_i is 6 hours per workday. If $K_S = 2$ and $V_w = 2500$ ft/hr, then $K_i = 6.67 \times 10^{-5}$ ft.$^{-1}$ and, if S = 1000 ft., then $K_i S = 0.067$. Accordingly,

$$\frac{C_i}{P_i T_i} \left(\frac{1}{1 - K_i S} \right) = \$178.57/\text{acre} \quad .$$

Note that $C_i/P_i T_i = \$166.67$/acre is the basic cost for lopping and scattering in this example, where no time is used walking from the roadside to the work site.

LOGGING COSTS

Logging comprises three major elements: (1) falling, limbing and bucking, (2) yarding or skidding, and (3) loading and hauling.

In most circumstances, the falling system is a sawyer and chainsaw and, as such, can be treated in a manner analogous to that used for other labor intensive work. That is, the sawyer must spend time walking to and from his work site each day--just as does a timber cruiser or tree planter--and the amount of such time depends on the average distance between roads. During the remaining available time, the sawyer will have an hourly production rate, say P_f, that is most conveniently expressed in volume or number of stems or logs processed per hour. The cost for a sawyer, say C_f, can be expressed in dollars per day.

If $\overline{V}$ represents the total volume (or number of stems or logs) per acre to be processed by the sawyer, then the cost per acre for falling, limbing and bucking (FC) during any particular entry can be expressed as

$$FC = \frac{C_f \overline{V}}{P_f T_f} \left(\frac{1}{1 - \frac{K_S S}{2 T_f V_w}} \right)$$

where P_f and $\overline{V}$ are expressed in compatible units. T_f is the available working hours in the workday and S, K_S, and V_w are as previously defined. Letting

$$K_f = \frac{K_S}{2 T_f V_w} \quad .$$

we can express falling, limbing and bucking costs as

$$FC = \frac{C_f\overline{V}}{P_f T_f} \left(\frac{1}{1 - K_f S}\right) .$$

It should be noted that P_f will depend on a large number of variables, including stand characteristics, silvicultural prescription, utilization standards, and terrain.

Skidding or yarding fallen timber is conducted by systems of workers and machines (or animals). Most of these systems require some time to set up or prepare to move wood, the amount of which depends on the average transport distance (or length of span, in the case of cable yarding systems). For example, ground skidding systems (e.g., horses or tractors) require skid trail clearing and landing preparations, and cable yarding systems must be moved from corridor to corridor. Perhaps only helicopters can be considered unique in this respect; whatever their necessary preparatory expenditures, they are generally unrelated to the yarding transport distance.

If the time, in minutes, spent in preparatory or rigging activities can be estimated as

$$R_0 + R_1 S$$

and the area served by a single set up (i.e., skid trail or corridor) is

$$b\ S$$

(where b is the average distance between skid trails or corridors, in feet), then the set-up or rigging time, in hours/acre, for skidding or yarding is

$$\frac{43560}{(60)b} \left(\frac{R_0}{S} + R_1\right) .$$

Now, if the average skidding or yarding cycle time, in minutes, can be expressed as

$$Y_0 + Y_1 S + Y_2 b + Y_3 n$$

(where n is the average number of stems or logs extracted per cycle and Y_0, Y_1, Y_2 and Y_3 are time coefficients), then the operating time, in hours per acre, for skidding or yarding will be

$$\frac{(\overline{V} + V_R)}{60(v)} \quad (Y_0 + Y_1 S + Y_2 b + Y_3 n) \quad ,$$

where v is the average volume per cycle and V_R represents the residues quantity to be extracted per acre in excess of the quantity processed by the sawyers ($\overline{V}$), all expressed in equivalent units. Therefore, the total yarding or skidding cost, in dollars per acre, will be

$$YC = \frac{C_y}{60T_y} \left[\frac{43560}{b} \left(\frac{R_0}{S} + R_1\right) + \frac{(\overline{V} + V_R)}{v} \quad (Y_0 + Y_1 S + Y_2 b + Y_3 n)\right]$$

where C_y is the daily cost, in dollars, for the yarding or skidding system, and T_y is the available on-site hours per workday.

Finally, we may assume that loading and hauling costs relate only to volume, so the cost per acre for these operations may be expressed simply as

$$HC = C_h \, (\overline{V} + V_R)$$

where C_h is the loading and hauling cost per unit volume, with the unit volume being consistent with the units of $\overline{V}$ and V_R.

APPENDIX B

Effects of Road Spacing or Span

To examine this matter, we make the assumptions listed in table B-I. Note that $K_S = 2$ (i.e., the yarding system can yard both uphill and downhill to the road system).

If S = 1000 feet, equation 8 yields

$$b_{opt} = \sqrt{\frac{43560 \text{ ft}^2/\text{acre} \left(0.3 \frac{\text{MBF}}{\text{cycle}}\right)\left(\frac{30 \text{ min.}}{1000 \text{ ft.}} + 0.03 \frac{\text{min.}}{\text{ft}}\right)}{(0.0125 \text{ min/cycle - ft})\ (10 \text{ MBF/acre})}}$$

or $b_{opt} = 79.2$ ft.;

and equation 9 yields

$$C = 4.125 \left(\frac{50{,}000}{1000}\right) + 210 \left[\frac{1}{1 - 0.05}\right] + 20\ (10) \left[\frac{1}{1 - 0.05}\right] + \frac{1000}{60(8)} \left\{ 2 \sqrt{\frac{43560\ (0.0125)\ (10) \left(\frac{30}{1000} + 0.03\right)}{0.3}} + \frac{10}{0.3} \left[3 + 0.0025\ (1000) + 0.1\ (3)\right] \right\} + 20\ (10)$$

or $C \approx \$1378$/acre.

Table B-II shows the total management cost (C) and components thereof, the daily production rate (P), and the optimum spacing between corridors versus yarding distance or span (S) under the assumptions in table B-I. Note that the daily production rate is determined from

$$P = \frac{C_y \overline{V}}{YC}$$

Table B-I.--Basic assumptions.

$\frac{C_f}{P_f T_f}$ = \$20/M bd.ft.

C_h = \$20/M bd. ft.

C_R = \$50,000/mi

C_y = \$1,000/day

K_A = 1

K_S = 2

$$\sum_{i=1}^{m} \frac{C_i}{P_i T_i} = \$210/\text{acre}$$

n = 3 pieces/cycle

R_0 = 30 min

R_1 = 0.03 min/ft

T_i = 8 hours/day; $i = 1, 2, \ldots m$

T_y = 8 hours/day

$\overline{V}$ = 10 M bd. ft./acre

V_R = 0

V_w = 2,500 ft/hr

Y_0 = 3 min/cycle

Y_1 = 0.0025 min/cycle-ft.

Y_2 = 0.0125 min/cycle-ft.

Y_3 = 0.1 min/cycle-piece

v = 0.3 M bd. ft./cycle

$$K_R = \frac{43560}{5280 K_A K_S} = 4.125 \text{ ft-mi/acre}$$

$$K_f = K_i = \frac{K_S}{2 T_i V_w} = 5\text{x}10^{-5} \text{ ft}^{-1}; \; i=1, 2, \ldots m$$

Table B-II.--Costs and production rates vs. span, under the assumptions in table B-1.

S (ft)	b_{opt} (ft)	RC ($/acre)	LIC ($/acre)	FC ($/acre)	YC ($/acre)	HC ($/acre)	C ($/acre)	P (M bd. ft./day)
250	125.2	825	212.7	202.5	490.0	200	1,930.2	20
400	104.8	515.6	214.3	204.1	480.5[1]	200	1,614.5	21
500	97.0	412.5	215.4	205.1	484.4	200	1,517.4	21
1,000	79.2	206.2	221.1	210.5	540.3	200	1,378.1	19
1,100	77.4	187.5	222.2	211.7	554.5	200	1,375.9[1]	18
2,000	68.6	103.1	233.4	222.2	695.5	200	1,454.2	14
3,000	64.7	68.8	247.1	235.3	862.3	200	1,613.5	12
4,000	62.6	51.6	262.5	250.0	1,032.3	200	1,796.4	10
5,000	61.3	41.2	280.0	266.7	1,203.7	200	1,991.6	8

[1]Designates minimum costs.

APPENDIX C

Effects of Reducing Cutting Intensity

Continued controversy relative to timber harvesting, and a tendency to increase the use of selective or partial cutting, tend to reduce the volumes per acre. Thus, consider the effect of reducing $\overline{V}$ from 10 M bd. ft./acre to 5 M bd. ft./acre, while retaining all remaining assumptions in table B-I. The resulting costs are shown in table C-I, and they show that the optimum yarding distances with respect to both yarding cost alone and total management cost are increased in comparison with table B-II. Moreover, the economic penalties incurred in total management cost by extending yarding distances beyond optimum are less severe as volume removed per acre is decreased.

Table C-I.--Costs and production rates vs. span for selective logging example. (C_1 = total first entry management cost)

S (ft)	b_{opt} (ft)	RC ($/acre)	LIC ($/acre)	FC ($/acre)	YC ($/acre)	HC ($/acre)	C_1 ($/acre)	P (M bd. ft./day
250	177.1	825	212.7	101.3	290.0	100	1,529.0	17
500	137.2	412.5	215.4	102.6	277.1[1]	100	1,107.6	18
1,000	112.0	206.2	221.1	105.2	298.6	100	931.1	17
1,500	102.2	137.5	227.0	108.1	333.5	100	906.1[1]	15
2,000	97.0	103.1	233.4	111.1	372.4	100	920.0	13
3,000	91.5	68.8	247.1	117.6	454.4	100	987.9	11
4,000	88.5	51.6	262.5	125.0	538.7	100	1,077.8	9
5,000	86.8	41.2	280.0	133.4	623.9	100	1,178.5	8

[1]Designates minimum costs.

Of course, when costs are expressed in terms of the merchantable volume removed, they become higher as volume decreases, as shown in Table C-II.

Table C-II.--Comparison of costs per unit of merchantable volume for complete ($C/\overline{V}$) and partial ($C_1/\overline{V}_1$) removal on first entry.

S (ft)	$C/\overline{V}$ [1] $\overline{V}$ = 10 M bd. ft./acre ($/M bd. ft.)	$C_1/\overline{V}_1$ $\overline{V}_1$ = 5 M bd. ft./acre ($/M bd. ft.)
250	193.0	305.8
500	151.7	221.5
1,000	137.8	186.2
2,000	145.4	184.0
3,000	161.4	197.6
4,000	179.6	215.5
5,000	199.2	235.7

[1] Based on appendix B.

If, on second entry, the remaining volume ($\overline{V}_2$) is removed, where

$$\overline{V}_2 = \overline{V} - \overline{V}_1 = 10 - 5 = 5 \text{ M bd. ft./acre},$$

then we may assume no road costs but that all remaining costs are the same as in table C-I. Table C-III shows the total of the second entry management costs, C_2, as well as the combined total of first and second entry costs ($C_1 + C_2$) and the corresponding combined cost per unit volume, or

$$\frac{C_1 + C_2}{\overline{V}_1 + \overline{V}_2} = \frac{C_1 + C_2}{\overline{V}} \quad .$$

Table C-III.--Second entry costs and combined first and second entry costs vs. span for selective logging example.

S (ft)	C_2 ($/acre)	$C_1 + C_2$ ($/acre)	$(C_1 + C_2)/\overline{V}$ ($/M bd. ft.)
250	704.2	2,233.4	223.3
500	695.1	1,802.7	180.3
1,000	724.9	1,656.0	165.6
2,000	816.9	1,736.9	173.7
3,000	919.1	1,907.0	190.7
4,000	1,026.2	2,104.0	210.4
5,000	1,137.3	2,315.8	231.6

APPENDIX D

Effects of Residues Removal

Suppose (1) that residues with characteristics similar to merchantable timber (e.g., standing or down dead trees) are to be removed, (2) that their volume, V_R, is equivalent to 2.5 M bd. ft./acre, (3) that the sawyer's rates must be increased (to compensate for falling or processing the residues) from \$20 per M bd. ft. to \$25 per M bd. ft., and (4) that all else in table B-I remains unchanged. Accordingly, the total management cost per acre, $C_{\overline{V} + V_R}$, and the corresponding cost per merchantable volume would be as shown in table D-I.

Table D-1.--Total management cost per acre and per unit of merchantable volume vs. span for V_R = 2.5 M bd. ft./acre and C_f/P_fT_f = \$25/M bd. ft.

S (ft)	$C_{\overline{V} + V_R}$ (\$/acre)	$C_{\overline{V} + V_R}/\overline{V}$ (\$/M bd. ft.)
250	2,124.6	212.5
500	1,717.5	171.8
1,000	1,597.6	159.8
2,000	1,717.8	171.8
3,000	1,923.0	197.3
4,000	2,152.6	215.3
5,000	2,395.2	239.5

If removal of residues causes no reduction in other site treatment costs (e.g., slash disposal) then, to avoid economic penalty, it is necessary that the residues contain an equivalent net merchantable volume of ρV_R, where

$$\rho \geq \frac{\overline{V}}{V_R} \left(\frac{C_{\overline{V} + V_R}}{C} - 1 \right) .$$

Table D-II shows the minimum values of ρ needed to enable removal of the residues in this example.

Table D-II.--Minimum values of ρ vs. span for residues removal example ($\overline{V}$ = 10 M bd. ft./acre, V_R = 2.5 M bd. ft./acre)

S (ft)	$C_{\overline{V}+V_R}$[1] ($/acre)	C[2] ($/acre)	ρ
250	2,124.6	1,930.2	0.40
500	1,717.5	1,517.4	0.53
1,000	1,597.6	1,378.1	0.64
2,000	1,717.8	1,454.2	0.73
3,000	1,923.0	1,613.5	0.77
4,000	2,152.6	1,796.4	0.79
5,000	2,395.2	1,991.6	0.81

[1] From table D-I.
[2] From Table B-II.

APPENDIX E

Analysis of Aerial Yarding Systems Prospects

We may assume that "rigging time" for aerial systems is negligible, and that there is no lateral yarding component in the yarding cycle. Accordingly, we may rewrite the expression for total per acre management cost as

$$C = K_R \frac{C_R}{S} + \sum_{i=1}^{m} \frac{C_i}{P_i T_i} \left(\frac{1}{1 - K_i S}\right) + \frac{C_f \overline{V}}{P_f T_f} \left(\frac{1}{1 - K_f S}\right) + \frac{C_y}{60 T_y} \frac{(\overline{V} + V_R)}{v} (Y_0 + Y_1 S + Y_3 n) + C_h (\overline{V} + V_R) \quad . \qquad \text{(E-1)}$$

Consider first a "small" helicopter system. Assume its cost, C_y, is $2,000 per day; its speed is such that Y_1 = 0.00025 min/cycle-ft.; its load carrying capability is such that v = 0.1 M bd. ft./cycle and n = 1 piece/cycle; that Y_0 = 2 min/cycle; and that all else is as assumed in table B-I. Table E-I shows the resulting costs based on equation E-1, as well as the corresponding daily production rates. (Note that the production rates in table E-I are comparable to those for the yarding system in table B-II.)

Table E-I.--Costs and yarding production rates for small helicopter system.

S (ft)	RC ($/acre)	LIC ($/acre)	FC ($/acre)	YC ($/acre)	HC ($/acre)	C ($/acre)	P (M bd. ft./day)
250	825.0	212.7	202.5	901.0	200	2,341.2	22.2
500	412.5	215.4	205.1	927.1	200	1,960.1	21.6
1,000	206.2	221.1	210.5	979.2	200	1,817.0	20.4
2,000	103.1	233.4	222.2	1,083.3	200	1,842.0	18.5
3,000	68.8	247.1	235.3	1,187.5	200	1,938.7	16.8
4,000	51.6	262.5	250.0	1,291.7	200	2,055.8	15.5
5,000	41.2	280.0	266.7	1,395.8	200	2,183.7	14.3

Next, consider a relatively "large" helicopter system, costing $20,000 per day, and having a load carrying capability equivalent to $v = 2$ M bd. ft./cycle. As for the small helicopter, we assume $Y_1 = 0.00025$ min/cycle-ft. and $Y_0 = 2$ min/cycle. However, we assume also that falling costs are doubled, owing to the need to gather or bunch stems or logs such that $n = 1$ "piece"/cycle. (We are assuming here the existence of some unspecified technology that would permit a sawyer or team of sawyers to maneuver logs or stems over short distances on steep slopes such that small piles or bunches equivalent to the helicopter's load capability would result.) Table E-II shows the costs and production rates for this system.

Table E-II.--Costs and yarding production rates for large helicopter system.

S (ft)	RC ($/acre)	LIC ($/acre)	FC ($/acre)	YC ($/acre)	HC ($/acre)	C ($/acre)	P (M bd. ft./day)
250	825.0	212.7	405.0	450.5	200	2,093.2	444
500	412.5	215.4	410.2	463.5	200	1,701.6	432
1,000	206.2	221.1	421.0	489.6	200	1,537.9	408
2,000	103.1	233.4	444.4	541.7	200	1,522.6	369
3,000	68.8	247.1	470.6	593.8	200	1,580.3	337
4,000	51.6	267.5	500.0	645.8	200	1,659.9	310
5,000	41.2	280.0	533.4	697.9	200	1,752.5	287

Finally, we assume the possibility of using some new, large capacity airship costing $20,000 per day and having a load capacity of $v = 10$ M bd. ft./cycle and a cruising speed equivalent to $Y_1 = 0.0005$ min./cycle-ft. We will further assume that its acceleration and deceleration rates, and its load retrieval rates, are such that $Y_0 = 4$ min/cycle and $Y_3 = 1$ min/cycle-piece; and again that $n = 1$ "piece"/cycle and that falling costs are doubled to account for load concentration in the woods. Table E-III shows the estimated costs and production rates for this system.

Table E-III.--Costs and production rates for hypothetical airship.

S (ft)	RC ($/acre)	LIC ($/acre)	FC ($/acre)	YC ($/acre)	HC ($/acre)	C ($/acre)	P (M bd. ft./day)
250	825.0	212.7	405.0	213.5	200	1,856.2	937
500	412.5	215.4	410.2	218.8	200	1,456.9	914
1,000	206.2	221.1	421.0	229.2	200	1,277.5	873
2,000	103.1	233.4	444.4	250.0	200	1,230.9	800
3,000	68.8	247.1	470.6	270.8	200	1,257.3	739
4,000	51.6	262.5	500.0	291.7	200	1,305.8	686
5,000	41.2	280.0	533.4	312.5	200	1,367.1	640
10,000	20.6	420.0	800.0	416.7	200	1,857.3	480
15,000	13.8	840.0	1,600.0	520.8	200	3,174.6	384

APPENDIX F

Analysis of Cable Yarding System Prospects

Consider the optimistic prospect that, by pre-bunching in advance of yarding, the average load capacity could be doubled. Consider further that carriage speed could be doubled and that, because of pre-bunching, the system cost could be reduced by 25 percent as a result of labor savings. Finally, assume that pre-bunching could be accomplished by sawyers through some unspecified technology that would merely double their production costs.

In accordance with our optimism, let v = 0.6 M bd. ft./cycle; Y_1 = 0.00125 min/cycle-ft; C_y = \$750/day; C_f/P_fT_f = \$40/M bd. ft.; n = 2 "pieces"/cycle; and assume that all remaining values are as in table B-I. The results are shown in table F-I, based on equations 8 and 9 in the text.

Table F-I.--Costs and production rates vs. span for optimistic improvements in cable yarding technology.

S (ft)	b_{opt} (ft)	RC ($/acre)	LIC ($/acre)	FC ($/acre)	YC ($/acre)	HC ($/acre)	C ($/acre)	P (M bd. ft./day)
250	177.1	825.0	212.7	405.0	206.8	200	1,849.5	36
500	137.2	412.5	215.4	410.2	188.9	200	1,427.0	40
1,000	112.0	206.2	221.1	421.0	188.8	200	1,237.1	40
2,000	97.0	103.1	233.4	444.4	211.6	200	1,192.5	35
3,000	91.5	68.8	247.1	470.6	240.5	200	1,227.0	31
4,000	88.5	51.6	262.5	500.0	271.2	200	1,285.3	28
5,000	86.8	41.2	280.0	533.4	302.6	200	1,357.2	25

APPENDIX G

Combination Yarding and Forwarding Systems

Consider the possibility that trail-based harvesting technologies could be devised such that yarding systems capable of spanning 1,000 feet could be maneuvered on trails, and that forwarding systems could move logs on these trails to truck roads. Obviously, personnel could also be readily transported on the trails.

Let the average distance between truck roads be represented by 2S, and assume that the average distance between trails would be 0.2S. If C_T represented the total cost per mile for trails, and if $K_A = 1$, then the average cost per acre served by the trails would be

$$TC = \frac{43560C_T}{5280(0.2S)} = 41.25 \quad \frac{C_T}{S} \quad .$$

Obviously, the cost per acre served by the truck roads would still be

$$RC = 4.125 \quad \frac{C_R}{S} \quad .$$

Now, based on our prior analysis, the cost per acre for labor intensive work, including falling, would be multiplied by a factor of

$$\left(\frac{1}{1 - \frac{0.1S}{T_i V_w}} \right) \quad ,$$

because the walking distance would have been reduced by a factor of 10. Similarly, the model for yarding cost would be modified; thus,

$$YC = \frac{C_y}{60T_y} \left[\frac{43560}{b} \left(\frac{R_0}{0.1S} + R_1 \right) + \frac{\left(\overline{V} + V_R\right)}{v} \left(Y_0 + 0.1Y_1S + Y_2b + Y_3n \right) \right] \quad .$$

Our forwarding system would cost C_F dollars per day, and its average travel distance would be S/2. Accordingly, the hours spent per acre for forwarding would be

$$\frac{\left(\overline{V} + V_R\right)}{60v_f} \left(Y_{f0} + Y_{f1}S + Y_{f3}n_f \right)$$

where v_f is the volume carried per forwarding cycle; Y_{f0} is the average fixed amount of time, in minutes, spent in each cycle (such as for maintenance, decking of logs at the truck roads, etc.); Y_{f1} is the travel time coefficient in min/cycle-ft.; Y_{f3} is the minutes per piece for loading and unloading the forwarder; and n_f is the number of pieces transported per cycle.

Accordingly, if loading of trucks and truck hauling costs remained the same as at present,

$$\text{or } C_h \left(\overline{V} + V_R\right) \quad ,$$

then our total cost per acre would become

$$C = 4.125\,\frac{C_{\mathcal{R}}}{S} + 41.25\,\frac{C_{\mathcal{T}}}{S} + \sum_{i=1}^{m} \frac{C_i}{P_i T_i}\left(\frac{1}{1 - \frac{0.1S}{T_f V_w}}\right) + \frac{C_f \overline{V}}{P_f T_f}\left(\frac{1}{1 - \frac{0.1S}{T_f V_w}}\right) + \frac{C_y}{60T_y}\left[\frac{43560}{b}\left(\frac{R_0}{0.1S} + R_1\right) + \frac{(\overline{V} + V_{\mathcal{R}})}{v}(Y_0 + 0.1Y_1 S + Y_2 b + Y_3 n)\right] + \frac{C_F}{60T_F}\,\frac{(\overline{V} + V_{\mathcal{R}})}{v_f}(Y_{f0} + Y_{f1}S + Y_{f3}n_f) + C_h(\overline{V} + V_{\mathcal{R}}) \quad . \tag{G-1}$$

The optimum spacing between yarding corridors would now be

$$b_{opt} = \sqrt{\frac{43560(v)\left(\frac{R_0}{0.1S} + R_1\right)}{Y_2(\overline{V} + V_{\mathcal{R}})}} \quad , \tag{G-2}$$

so that when equation G-2 is substituted for b in equation G-1, the total per acre management cost becomes

$$C = 4.125\,\frac{C_{\mathcal{R}}}{S} + 41.25\,\frac{C_{\mathcal{T}}}{S} + \sum_{i=1}^{m} \frac{C_i}{P_i T_i}\left(\frac{1}{1 - \frac{0.1S}{T_f V_w}}\right) + \frac{C_f \overline{V}}{P_f T_f}\left(\frac{1}{1 - \frac{0.1S}{T_f V_w}}\right) + \frac{C_y}{60T_y}\left[2\sqrt{\frac{43560\,Y_2\,(\overline{V} + V_{\mathcal{R}})\,(R_0/0.1S + R_1)}{v}} + \frac{(\overline{V} + V_{\mathcal{R}})}{v}(Y_0 + 0.1Y_1 S + Y_3 n)\right] + \frac{C_F}{60T_F}\,\frac{(\overline{V} + V_{\mathcal{R}})}{v_f}(Y_{f0} + Y_{f1}S + Y_{f3}n_f) + C_h(\overline{V} + V_{\mathcal{R}}) \quad . \tag{G-3}$$

Now, because we would be operating from trails, it is likely that forwarding rates would have to be compatible with yarding rates. Accordingly, before proceeding further, we should examine whether operation in this fashion would be technically feasible.

Compatibility of Forwarding and Yarding Systems

Compatibility of the forwarding and yarding systems means essentially that the time spent per acre by each of the systems should be approximately equal, or that

$$2\sqrt{\frac{43560\,Y_2\,(\overline{V} + V_{\mathcal{R}})\left(\frac{R_0}{0.1S} + R_1\right)}{v}} + \left(\frac{\overline{V} + V_{\mathcal{R}}}{v}\right)(Y_0 + 0.1Y_1 S + Y_3 n) = \frac{(\overline{V} + V_{\mathcal{R}})}{v_f}(Y_0 + Y_{f1}S + Y_{f3}n_f) \quad .$$

From this we can obtain

$$Y_{f1} = \frac{v_f}{(\overline{V} + V_{\mathcal{R}})S}\left[2\sqrt{\frac{43560\,Y_2\,(\overline{V} + V_{\mathcal{R}})\left(\frac{R_0}{0.1S} + R_1\right)}{v}} + \frac{(\overline{V} + V_{\mathcal{R}})}{v}(Y_0 + 0.1Y_1 S + Y_3 n) - \frac{(\overline{V} + V_{\mathcal{R}})Y_{f0}}{v_f} - (\overline{V} + V_{\mathcal{R}})Y_{f3}\,\frac{n_f}{v_f}\right] \quad .$$

Because our yarding system is likely to be of lower power and lower load carrying capability than conventional systems, n and v will probably be less, and Y_1 will probably be greater than for conventional systems. Nevertheless, to be conservative, we will assume these factors to be unchanged--that is, that n = 3 pieces/cycle, v = 0.3 M bd. ft./cycle, and Y_1 = 0.0025 min/cycle-ft.

We will assume further that $Y_{f0} = Y_0$ = 3 min/cycle, but that $Y_{f3} = 10\ Y_3$ = 1 min/piece (recall from table B-I that Y_3 = 0.1 min/cycle-piece). Retaining Y_2 = 0.0125 min/cycle-ft, $(\overline{V} + V_R)$ = 10 M bd. ft./acre, R_0 = 30 min, R_1 = 0.03 min/ft, and assuming $n_{f/v_f} = n/v$ = 10 pieces/M bd. ft., we obtain the following relationship:

$$Y_{f1} = 0.1 \frac{v_f}{S} \left[269.4 \sqrt{\frac{300}{S} + 0.03} + 33.3\ (3.3 + 0.00025S) - \frac{30}{v_f} - 100 \right]$$

Our worst condition would occur when S is large and v_f is small. Suppose, for example, that S = 10,000 feet and $v_f = 2v$ = 0.6 M bd. ft. /cycle. Then Y_{f1} would have to be less than or equal to 0.00065 min/cycle-ft, which is equivalent to an average forwarder speed of 1 ÷ 0.00065 = 1538 ft/min, or about 17 miles per hour. If $v_f = 4v$ = 1.2 M bd. ft./cycle, and S = 10,000 feet, the average forwarder speed would only need to be about 7 miles per hour.

In short, it would appear technically feasible to maintain forwarder production equivalent to yarder production over relatively long distances. Of course, the forwarder would probably be under-utilized at shorter distances, but for simplicity and conservatism, we will assume the forwarding costs would be lumped with yarding costs. Accordingly, we may rewrite equation G-3 as follows:

$$C = 4.125 \frac{C_R}{S} + 41.25 \frac{C_T}{S} + \sum_{i=1}^{m} \frac{C_i}{P_i T_i} \left(\frac{1}{1 - \frac{0.1S}{T_i V_w}} \right) + \frac{C_f \overline{V}}{P_f T_f} \left(\frac{1}{1 - \frac{0.1S}{T_f V_w}} \right) + \frac{(C_y + C_F)}{60T_y} \left[2\sqrt{\frac{43560\ Y_2\ (\overline{V} + V_R) \left(\frac{R_0}{0.1S} + R_1 \right)}{v}} \right.$$

$$\left. + \frac{(\overline{V} + V_R)}{v} (Y_0 + 0.1Y_1 S + Y_3 n) \right] + C_h\ (\overline{V} + V_R) \quad . \qquad \text{(G-4)}$$

Assuming $C_y + C_F$ = \$1,000/day, that $C_T = 0.1\ C_R$ = \$5,000/mi, and that all other values remain the same as in table B-I, we obtain the results listed in table G-I.

Table G-I.--Costs and production rates vs. S for combined yarding and forwarding system.

Road Spacing (ft)	S (ft)	b_{opt} (ft)	RC ($/acre)	TC ($/acre)	LIC ($/acre)	FC ($/acre)	Yard & forward ($/acre)	HC ($/acre)	C ($/acre)	P (M bd. ft./day)
2,000	1,000	185.7	206.3	206.3	211.1	201.0	569.0	200	1,593.7	18
4,000	2,000	137.2	103.1	103.1	212.1	202.0	502.0	200	1,322.3	20
8,000	4,000	104.8	51.6	51.6	214.3	204.1	480.5	200	1,202.1	21
12,000	6,000	91.5	34.4	34.4	216.5	206.2	492.1	200	1,183.6[1]	20
16,000	8,000	84.0	25.8	25.8	218.8	208.3	513.9	200	1,192.6	19
20,000	10,000	79.2	20.6	20.6	221.1	210.5	540.3	200	1,213.1	18

[1]Designates optimum.

OUTLOOK AND OPPORTUNITY FOR WHOLE-TREE CHIP QUALITY IMPROVEMENT

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ABSTRACT

Three processes have been developed in the United States, one in Canada, and one in Finland for improving the quality of whole-tree and forest residue chips. They have potential application individually or in combination. Two of them have been applied commercially by the pulp and paper industry. Application of these processes coupled with integrated utilization of the various output wood, bark, and foliage fractions for fiber and energy products should promote the recovery of more forest residues.

KEYWORDS: bark removal, residues, biomass, utilization, foliage removal

INTRODUCTION

The demand for wood and fiber products is projected to increase due to high energy costs and a decreasing forest land base. The forest industry can help meet the projected increase by improving the recovery and utilization of forest residues.

Enormous quantities of forest residues are generated annually throughout the country. In the Eastern United States, there is an estimated potential annual supply of slightly over 200 million dry tons (USDA Forest Service 1978). National forests in the Pacific Northwest, California, and Northern Rocky Mountains annually generate 24 million, 15 million, and 5.5 million tons respectively of residue (Lowery and Host 1978). The cost of extracting and processing these residues for wood fiber products or other uses exceeds that of using available standing round wood or sawmill residues.

Whole-tree harvesting could recover a large portion of these unutilized materials economically. By this method entire trees are skidded to the landing, the more valuable saw logs are bucked out, then the tops and limbs are chipped. Non-saw-log trees, including culls, are chipped on the spot. Whole-tree harvesting should result in lower residue recovery costs for the following reasons:

- The available fiber is more completely utilized by chipping of tops, limbs, small trees, and other material currently abandoned as residues. Yield increases in tons per acre over conventional harvesting can reach 150 percent.
- Slash treatment, site preparation, and regeneration costs are reduced by removal of all the material from the stand.
- Chips can be handled easier than round wood. Chips are small and can be transported continuously as a bulk commodity over long or short distances using belts, conveyors, or pneumatic pipelines.
- Since several trees can be chipped at a time if the stems are small, chipping productivity is unaffected by tree size.
- Delimbing and bucking are reduced considerably. Only the saw log portion of trees requires delimbing and bucking.

Four factors that have promoted the great activity in research, development, and utilization of whole-tree chips are the steady growth of pulp markets, the abrupt increases in the cost of energy, the increasing public and environmental pressure to more fully utilize the forest biomass, and the development of mechanized harvesting.

The amount of whole-tree or unbarked chips acceptable in a specific mill depends upon its pulping process, cleaning facilities, and end product specifications. A number of pulp mills are using whole-tree or forest residual chips by blending small percentages of them with other "clean" chips. Although some mills have used over 30 percent barky chips, most mills have limited their use to less than 20 percent. The number of mills using whole-tree chips has decreased in recent years due to an adequate supply of clean chips and/or problems that were encountered in their initial trials with whole-tree chips. Widespread use of forest residues for pulp and paper will depend on methods for improving the quality of forest residual chips.

To increase utilization, field chipping of residues--including whole trees--must be coupled with an effective system for removing the bark from the chip mass. This paper reviews significant progress made in bark segregation in the United States, Canada, and Finland. The segregation processes developed have the potential of not only upgrading residue chips but also producing a valuable fuel. The processes could be the key to an integrated fiber and fuel raw material supply system for the future.

RESEARCH BY THE USDA FOREST SERVICE

Research in improving whole-tree chip quality has been conducted by the North Central Forest Experiment Station's Forestry Sciences Laboratory at Houghton, Michigan. The research has resulted in three promising processes--steaming-compression debarking, vacuum-airlift segregation, and photosorting (Arola and Erickson 1973; Mattson 1975; Sturos 1978; Sturos and Brumm 1978). Combinations of the above processes are also possible.

The patented steaming-compression debarking process (Erickson and Hillstrom 1974) basically consists of three steps: (1) presteaming the unbarked chip mass, (2) passing the chips through a compression debarker, and (3) screening the compression debarker output to remove fines (fig. 1). Additional (optional) steps include mechanical attrition of the smaller chip output fractions followed by screening to remove additional fines.

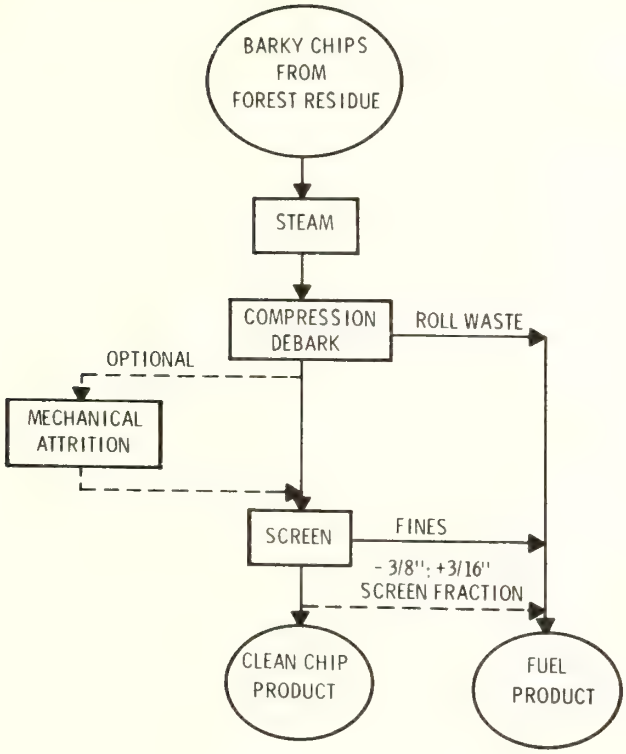

Figure 1.--Flow chart of the steaming-compression system for upgrading forest residue chips.

Bark removal tests have been conducted with western forest residues using the steaming-compression debarking process (Arola and Host 1976). Bark removal ranged from 60 to 85 percent and wood recovery from 87 to 92 percent with the lodgepole pine, ponderosa pine, Douglas-fir, and western larch residue chips. The output bark content ranged from 1 percent for lodgepole pine to 7 percent for western larch. However, by rejecting the 3/16-inch screen fraction from the output, bark content in the output was reduced to less than 4 percent for all four species. This, however, decreased the wood recovery to a range of 72 to 84 percent.

Successful chip debarking trials have also been conducted with three additional western species, namely, western hemlock, red alder, and bigleaf maple (Hillstrom 1974). Best results were obtained with red alder; more than 92 percent of the input bark was removed and 92 percent of the input wood fiber was recovered (table 1). The clean output chips had a bark content of 1.7 percent compared to 20.4 percent in the input.

The Forest Service steaming-compression debarking process has been put into practice commercially by Parsons & Whittemore, Inc. who designed and built a debarking plant at their St. Anne Nackawic pulp mill in New Brunswick, Canada. The plant has been operating since April 1975 processing all of their hardwood whole-tree chips. The plant capacity is rated at 10 oven-dry tons per hour. The bark content of their whole-tree chips has been reduced from 12 to 3.6 percent with a wood loss of 9 percent (Wawer and Misra 1977). One major advantage of the compressed chips is that the cooking time in the digester decreased by 9 percent.

Table 1.--Compression debarking of whole-tree chips of four western species (Hillstrom 1974)

(In percent)

Species	Treatment[1]	Input bark	Output bark	Bark removed	Wood recovered
Western hemlock	SCD	16.0	4.1	74	92
Douglas-fir	CD	15.5	7.9	49	91
Red alder	SCD	20.4	1.7	92	92
Bigleaf maple[2]	CD	15.8	5.8	64	92

[1]SCD - Presteaming, compression debarking, and mechanical attrition
CD - Compression debarking and mechanical attrition.
[2]Chips produced from stem only.

A second steaming-compression debarking pilot plant has been erected and operated at Saint-Gaudens, France, by Groupement Européen de la Cellulose (GEC) (Tyrode et al. 1977). The process consists of four stages as follows: prescreening, steaming, compression debarking, and postscreening. After 1 year of operation the bark level of a mixture of French hardwoods has been reduced from 18.8 percent to 7.8 percent with 5 percent or less wood loss. The compressed hardwood chips have not modified the physical properties of the pulp made with their kraft process. A better liquor penetration has been obtained, thereby requiring less alkali and a reduction in pulp screenings. Promising results have also been obtained with softwoods.

A 60 green ton per hour debarking plant using presteaming, compression debarking, and screening should process whole-tree chips for an estimated $7.58 per dry output ton, exclusive of raw materials costs (Biltonen et al. 1979). The total physical plant cost is estimated to be about $4 million, including about $1.6 million for the process equipment.

A vacuum-airlift segregator has also received laboratory scale testing both by the USDA Forest Service and by industry (Sturos and Marvin 1978). This consists of a wire mesh conveyor belt with vacuum hoods placed above the belt at various stations (fig. 2). Whole-tree chips are spread over a continuously moving conveyor belt passing through fields of air currents that subject the chips to vacuum forces from above the belt. The material is then segregated on the basis of differences in terminal settling velocities caused by density and geometric differences. Typically in a multiple-stage system, foliage, clean wood chips, and middlings are removed at different locations along the belt. Bark, knots, and twigs remain on the belt to discharge to a hog fuel product area. Fines, including bark, foliage, dirt, and grit, fall through the mesh belting and discharge to the hog fuel pile.

The "middlings" fraction contains from 30 to 50 percent of the total input material, depending on species, and has a bark content equal to or greater than the as-received whole-tree chips. This fraction can be used for pulp, particleboard, fuel, or chemicals. If the middlings are to be used for pulp, further beneficiation by the compression debarking process is recommended.

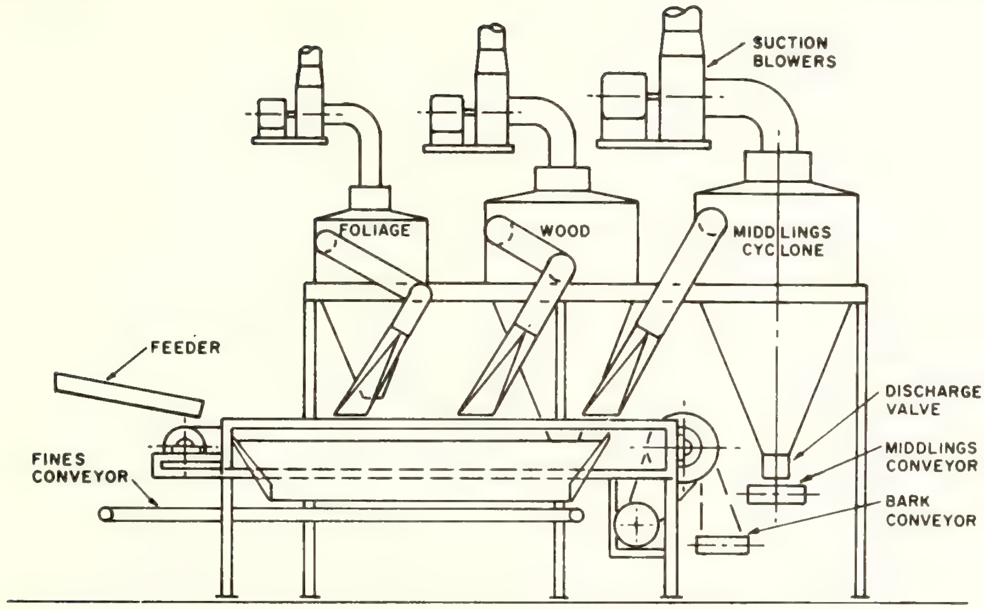

Figure 2.--Multiple-stage vacuum-airlift segregator. Fines fall through the wire mesh conveyor.

For maximum recovery of "clean" fiber, a combined system is recommended (fig. 3). It consists of vacuum-airlift segregation followed by steaming-compression debarking of the middlings. Typical results for Lake States aspen is as follows: By means of the vacuum-airlift stage, 4 percent of the input is removed as commercial foliage, 4 percent falls through the wire mesh conveyor as fines, 42 percent is recovered as clean wood chips acceptable for pulping, 36 percent is recovered as middlings, and 14 percent is left on the conveyor primarily as bark (fuel). Passing the middlings through the compression debarker results in an additional 29 percent clean wood chips and 7 percent bark. The combined product recovery results are 71 percent fiber, 25 percent fuel, and 4 percent foliage.

A limited amount of testing was conducted on western forest residues with vacuum-airlift segregation alone and in combination with compression debarking (Lowery et al. 1977). The vacuum-airlift stage recovered 38 to 85 percent of the input wood with bark levels of 1.5 to 3.6 percent (table 2). Processing the middlings from the vacuum-airlift segregator through the steaming-compression debarking process increased the wood recovery to 95 to 99 percent with bark levels of 1.9 to 5.1 percent in the combined output.

Several cost analyses of the steaming-compression debarking system, the vacuum-airlift system, and combinations of these two systems have revealed that the combined system is the most cost efficient. One of the primary advantages of coupling the vacuum-airlift segregator and the compression debarker is to decrease the amount of material the compression debarker has to process, which in turn reduced steam requirements and the size of the press. Therefore both capital equipment and beneficiation costs are reduced. The beneficiation costs (excluding raw material costs) are estimated to range from \$7.85 per dry ton of debarked chips for a steaming-compression debarking system, to \$5.60 for a combined system in which only 34 percent of the material is compression debarked. Total capital investment for a 60 ton per

hour debarking plant ranges from about $4 million for a steaming-compression debarking plant to $2 million for a combined vacuum-airlift and steaming-compression system.

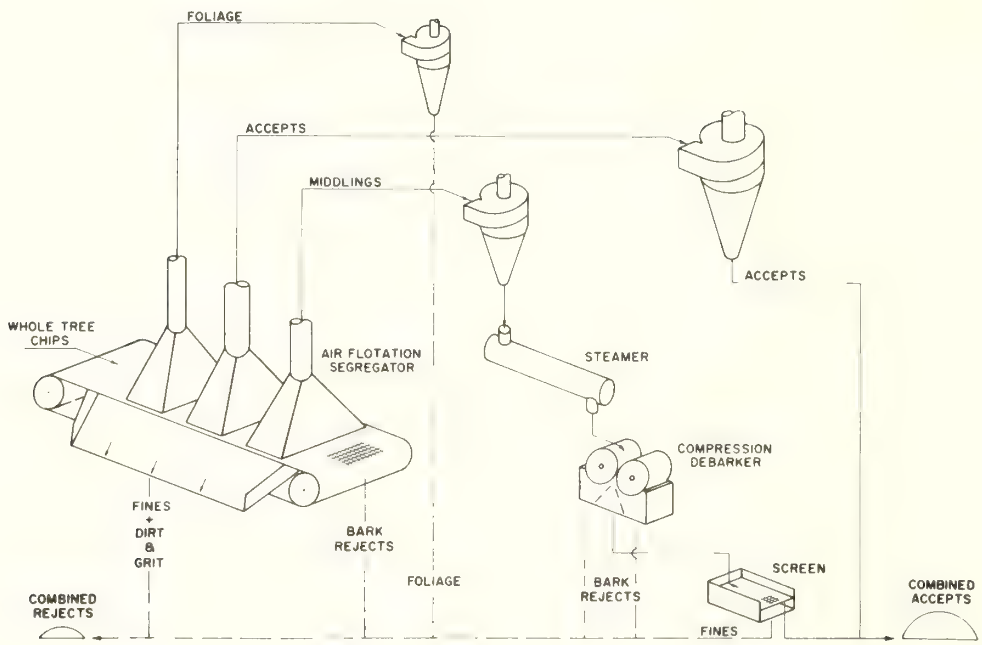

Figure 3.--Combined vacuum-airlift and steaming-compression debarking process for upgrading whole-tree and forest residual chips.

Table 2.--Bark removal results obtained with the vacuum-airlift system alone and in combination with the compression debarking system (Lowery et al. 1977)

(In percent, dry weight)

			Vacuum-airlift segregation		Vacuum-airlift and compression debarking		
Species	Condition	Input bark	Output bark	Wood recovered	Output bark	Bark removed	Wood recovered
Engelmann spruce	Green	13.4	3.0	79	4.1	73	99
Engelmann spruce	Dead standing	12.3	1.5	38	1.9	87	96
Western larch	Dead down	8.6	3.6	85	5.1	45	95

As mentioned earlier, the combined system is recommended for pulp mills needing a fiber supply where maximum "clean" wood recovery is the prime objective. In the near future many powerplants, both at forest industrial sites and others, will likely be fueled with whole-tree and/or forest residue chips. To help cover the potentially higher costs of recovering forest residues, an effort should be made to "scalp off" some clean pulp chips from the incoming wood because of the high value of pulp chips compared to fuel chips. As indicated in table 2, 38 to 85 percent of the input wood can be recovered with acceptable bark levels from western residue chips through the use of the vacuum-airlift segregator alone. Cost to install a 20 ton per hour vacuum-airlift system into an already existing plant has been estimated to be $175,000. The processing cost would be about $1 per input ton with a total connected horsepower of 205.

Photosorting has also been investigated at the laboratory scale by the USDA Forest Service. Wood and bark chips differ sufficiently in their optical transmittance to be sortable (Sturos and Brumm 1978). During photosorting, the chips are fed by a conveyor over a linear array of optical detectors (fig. 4). Light from an incandescent source is incident on the chips from above. The light intensity is adjusted so that most wood chips transmit sufficient light to be sensed by the detector array. When a bark chip passes over the detectors, the transmitted light falls below a preset detection threshold and the detector photo current decreases. The resulting signal is amplified to energize an air valve, which deflects the bark chips with a blast of air (fig. 5). Promising results have been obtained with three Lake States species, namely, balsam fir, white spruce, and aspen (table 3): 84 to 92 percent of the bark has been removed while recovering 58 to 65 percent of the wood. Photosorting should be considered as only a part of a total chip debarking system. It could be used ahead of the steaming-compression debarking process similar to the vacuum-airlift segregator, to "scalp off" a clean chip fraction. A modular 8 green ton per hour capacity photosorter is estimated to cost less than $40,000.

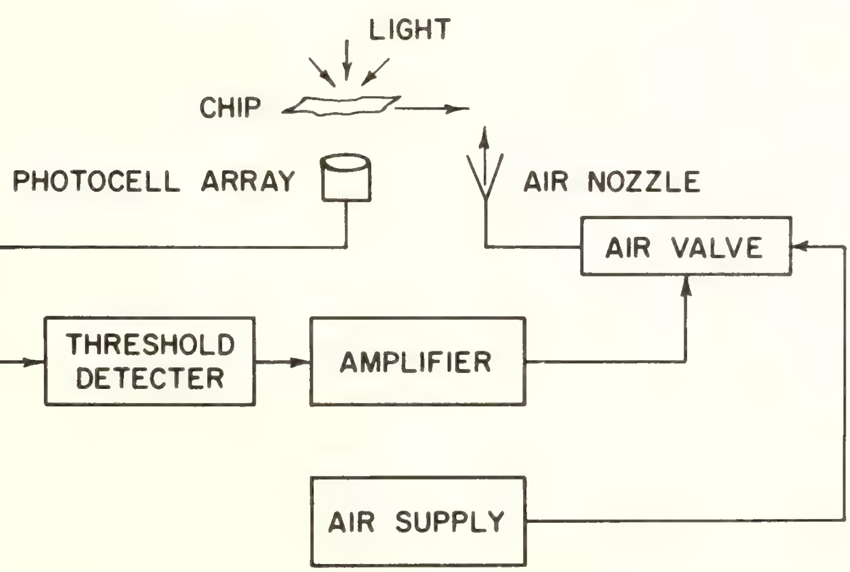

Figure 4.--Photosorting system diagram.

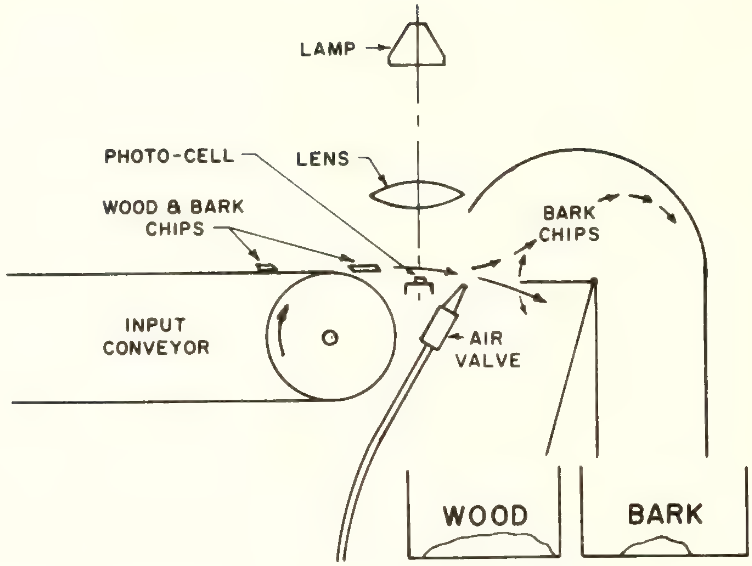

Figure 5.--Mechanical configuration of the photosorting system.

Table 3.--Typical photosorting results with the 5/8-inch size chips of three Lake States species

(In percent)

Species	Input bark	Output bark	Wood recovered	Bark removed
Balsam fir	10.2	1.3	64	92
White spruce	5.9	1.4	58	87
Aspen	10.3	2.7	65	84

RESEARCH BY PPRIC AND FERIC[1]

The Pulp and Paper Research Institute and the Forest Engineering Research Institute of Canada have developed a patented process for upgrading whole-tree chips (Berlyn et al. 1979). The method consists of three stages:

[1]PPRIC - Pulp and Paper Research Institute of Canada

FERIC - Forest Engineering Research Institute of Canada

- Conditioning by storing the chips in a pile or by steaming to increase the difference in strength between wood, bark, and foliage.
- Agitating in water to separate the bark and foliage from the wood and then breaking the bark and foliage down into small fragments.
- Segregating the fragmented bark and foliage from the wood chips by washing them over a screen plate.

Six weeks of storage in a chip pile or six to ten minutes of steaming at atmospheric pressure is generally required as a conditioning pretreatment. The process is designed to be set up as either a batch or continuous process. The Canadian researchers have experienced some problem with the thick outer bark on some species. However they do report good bark removal even from bark/wood chips (tight bark) and twigs, so as to reduce the bark/foliage content of whole-tree softwood chips from 20 percent to 2 percent with 91 to 96 percent wood recovery. They estimate the capital cost of a 220 O.D. ton per day batch process to be about $1 million with operating costs ranging between $3.70 and $7.40 per ton of whole-tree chips. The batch process would consist of a 15-minute processing cycle in a 12-foot diameter pulper (agitation chamber). Advantages noted are that the process has application to both softwood and hardwood and that the process uses no specialized or new equipment. Two disadvantages are the recycling and treatment of the waste water required and the low solid content of the bark/foliage fraction removed, thereby lowering the fuel value.

METHOD DEVELOPED IN FINLAND

A ballmilling process for beneficiating whole-tree and forest residual chips has been developed cooperatively in Finland by Kone Osakeyhtio and Enso-Gutzeit Oy (Hakkila et al. 1979). The process begins by removing oversized material, including stones, with a disc screen (fig. 6). This is followed by removal of iron tramp metal with a magnet. From this point the whole-tree chips are fed into a revolving ballmilling drum where the bark and foliage are fragmented and subsequently segregated from the wood by two stages of screening. The first screening stage is a thickness sort on a disc screen. Overthick chips are rechipped and fed back through the disc screen. The material which passes through the disc screen is then conveyed to a flat screen where long slivers (over-long particles) are removed. They are rechipped and screened again. The fines removed are collected as hog fuel.

Experimental results with pine, birch, and alder whole-tree chips indicate that 15.9 to 21.3 percent input bark can be reduced to 3.4 to 5.4 percent bark in the output material with a range of wood recovery of 87.6 to 92.5 percent. The hog fuel rejects represent 23-25 percent of the input. The experimental trials were conducted with a pilot scale chip debarking plant built at the Enso-Gutzeit Oy site in Imatra, Finland. The capacity of the plant is 8 to 12 solid cubic meters (20 to 30 loose cubic meters) per hour. The manufacturer, Kone Osakeyhtio, estimates that the capacity of the plant can be increased to the 40-120 solid cubic meters per hour level. The power requirements of the process range from 12 to 25 kilowatt-hours per solid cubic meter.

The developers of the process consider the debarked chips acceptable for sulphate pulping. In addition they claim the following advantages:

- Neither water nor chemicals are used.
- The fuel value of the reject material is high and waste water problems are avoided.
- The labor requirement is small.

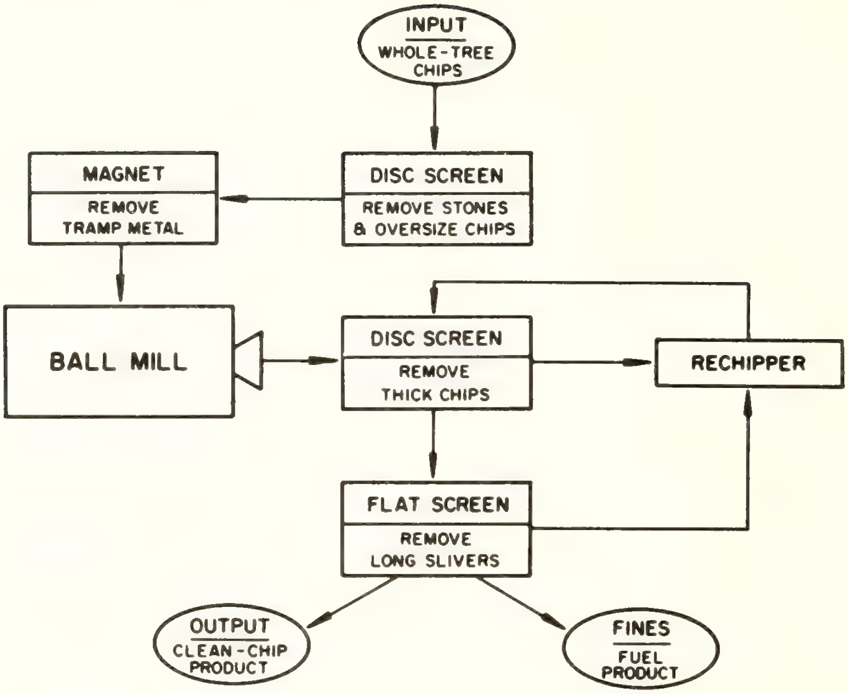

Figure 6.--Schematic of the Finnish ballmilling process for upgrading whole-tree chips.

SUMMARY

Significant progress has been made in developing the technology to improve the quality of whole-tree and forest residue chips. The USDA Forest Service has developed three methods: steaming-compression debarking followed by an optional ballmilling process, vacuum-airlift segregation, and photosorting. They have potential both individually and in combination. The steaming-compression debarking process has been scaled up to commercial pilot plants by St. Anne Nackawic Pulp and Paper Company, New Brunswick, Canada, and by Groupement Européen de la Cellulose (GEC), Saint-Gaudens, France. The Pulp and Paper Research Institute and the Forest Engineering Research Institute of Canada, Point Claire, Quebec, have developed a method for separating and breaking off bark. Whole-tree chips are exposed to microbial action during 6 weeks of storage and then subjected to heavy attrition motion in water in a device resembling a pulper. In Finland, Kone Osakeyhtio in cooperation with Enso-Gutzeil Oy has developed a whole-tree chip upgrading process based on ballmilling.

Certainly more and more residuals are going to be used in the future. Even though the major obstacle preventing widescale use of forest residues is the high harvesting and transporting costs, a considerable amount of tops and cull trees and logs can be recovered from ongoing logging operations by employing integrated harvesting techniques. The use of whole-tree chippers at the landing simultaneously with the saw log recovery system is usually the most economical way to recover residues for fiber and fuel.

To help pay for the high residue recovery costs, attention should be given to processing the residue chips so that they are allocated to the highest end value. The new chip upgrading processes presented in this paper can fractionate forest residue chips into clean wood chips for the pulp mill and bark, twigs, and poor quality wood chips for the boiler as hog fuel. The fuel value of the bark more than covers the operating cost of the chip debarking process.

Processes to improve whole-tree and residue chips will become a part of the total residue recovery system because they can provide both fiber and energy for the future. Fuller utilization of the forest biomass is rapidly becoming a necessity for the pulp and paper industry. Companies that do not provide close utilization for a sizable portion of their fiber and energy will find it more and more difficult to compete.

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EVALUATING IN-WOODS CHIPPING FEASIBILITY

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ABSTRACT

Economic analysis of data from a demonstration test showed that in-woods debarking-chipping was only marginally competitive with conventional methods of harvesting roundwood for pulp chips. The future for in-woods chipping appears to be whole tree chipping. Cost of delivered chips may not be much different from conventional roundwood systems unless credits are taken for increased utilization and slash disposal.

KEYWORDS: chipping machines, logging economics

In-woods chipping has received attention as an inexpensive means of producing pulp chips. Today, there is interest in using in-woods chipping in producing wood for energy. Whatever the intended use of the product, the technical and economic feasibility of in-woods chipping should be carefully evaluated before a commitment is made.

In 1973 the Rocky Mountain Forest and Range Experiment Station and National Forest and Range Experiment Station and National Forest System Regions 2 and 3 (Rocky Mountain and Southwestern), Four Corners Regional Commission, and Southwest Forest Industries, Inc. cooperated in a demonstration test of in-woods chipping. This paper presents an evaluation of the test results and uses the results to predict the future of in-woods chipping. The details of the demonstration test were reported in three published papers (Markstrom, Worth, and Garbutt, 1977; Sampson and Worth, 1976; Sampson, Worth and Donnelly, 1974).

IN-WOODS CHIPPING DEMONSTRATION TEST

The demonstration of in-woods chipping was a summer-long test in Arizona and Colorado. The chips produced were to be used for pulp. The receiving mill required that the chips be essentially bark-free.

System Used

The portable debarking-chipping machine used in the demonstration test was the Nicholson Logger Model Utilizer.1/ Trees were felled, limbed, and bucked with chainsaws by contract cutters, then bunched and skidded with rubber-tired and tracked skidders. Logs were stacked at the landing, partially by the skidders, and partially by a front-end loader. The self-loading debarker-chipper usually worked from a cold deck, although occasionally logs were skidded directly to it. Chips were blown directly into chip vans which hauled the chips either to the pulp mill or to a rail transfer point.

Study Area

The Arizona study area was part of an ongoing multiproduct sale in uneven-aged ponderosa pine timber marked for partial cutting. Sawtimber tops and trees smaller than sawtimber size (12 inches dbh) were being taken for pulpwood. Sawlogs and pulpwood were bucked at the stump and were skidded and decked together. Sawlogs were loaded and hauled from the decks leaving the pulpwood to be debarked and chipped at the landings. Some reskidding and consolidation of the pulpwood was necessary to obtain sufficient volumes in individual log decks. Chip haul distance from the woods to the pulp mill was about 75 miles.

The Colorado study area was an Engelmann spruce-subalpine fir tract marked for silvicultural thinning. It had been logged for sawtimber more than a year earlier. This area had a large volume of down and standing dead timber. All dead timber that was judged to be at least 50 percent sound was brought in along with the spruce-fir thinnings. Chips produced at the Colorado study area were truck hauled 146 miles to Gallup, New Mexico and reloaded on railroad cars for shipment the last 116 miles to the pulp mill.

Initial Concerns

Early questions about the feasibility of in-woods debarking-chipping were segregated into environmental concerns and economic concerns. While preliminary analyses had indicated in-woods debarking-chipping should be economically feasible, some problems were expected in the environmental realm.

ENVIRONMENTAL CONCERNS

It was expected that in-woods debarking-chipping would result in increased utilization and hence more wood removed per acre, but it was anticipated there would be little difference between the proposed system and conventional multi-product harvesting systems up to the point of debarking-chipping. Adverse environmental impacts from this part of the operation were not a major concern. However, there was concern about the size of forest openings necessary to accommodate the log deck, the debarker-chipper, chip vans, and turn around areas.

1/ The use of trade, firm, or corporation names does not constitute an official endorsement of or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

Another major environmental concern was possible soil sterilization (nitrogen starvation) caused by disposing of bark on site. We developed data showing the bark depths that would likely occur if the bark were uniformly spread around the landing. However, there was no previous research which could be used to accurately predict the biological effects of spreading the bark and leaving it.

ECONOMIC CONCERNS

While it was anticipated that actual debarking-chipping cost would be slightly higher in the woods than at a permanent installation, it was believed that lower costs in the other functions would more than offset this. Under the in-woods operation, measuring and bucking to bolt lengths could be eliminated, allowing some efficiency in limbing and bucking, and utilization could be improved slightly. Skidding is affected only slightly because volume per turn is increased by about 1 percent. With in-woods debarking-chipping, loading of roundwood is eliminated. Also, hauling of bark (10 to 12 percent of the volume) is eliminated. Offsetting these advantages in part, chip vans are slightly less maneuverable on forest roads than log trucks, which increases haul time.

Considering all functions except debarking-chipping, it was estimated that the in-woods system should provide a cost advantage of $0-$5.00 per bone dry unit. (A bone dry unit is 2,400 pounds of chips at zero moisture content.) At that time, the assumed mill chipping cost was $3.20 per unit. Thus, an in-woods debarking-chipping cost of $8.20 or less per unit should result in an overall cost that could be competitive with the conventional system. Preliminary analyses had indicated an in-woods cost of $5-$6.00 per unit.

Methods

During the demonstration test, most effort was devoted to monitoring the operation of the debarker-chipper. The nature of the environmental concerns was such that numerical data could not be taken for analysis. Instead, general observations were made about environmental problems identified earlier.

Detailed data were taken on the debarking-chipping operation throughout the demonstration test period. Planned starting and stopping times were recorded each day. Delays of one minute duration or longer were noted along with the cause. Estimated dimensions of each piece chipped (end diameters to the nearest inch and length to the nearest foot) were recorded. Taking such detailed data was important for a fair analysis to be made.

To determine probable costs under improved conditions, estimates of production when the machine as actually operating were developed and then realistic delays representing optimum conditions were applied. The debarker-chipper's production was significantly affected by the lineal feed rate and the rate at which the operator loaded individual pieces onto the machine. The mechanics of the debarking operation required that only one piece could be processed at a time, and design of the machine resulted in a 6-foot space between pieces as they fed into the debarker. A computer simulation model incorporationg these characteristics was developed to predict chipping rate for various loading rates using data from the logs actually chipped as input.

Results

ENVIRONMENTAL IMPACTS

In the ponderosa pine type the landing sizes that resulted were acceptable to forest managers. Ten landings were used for chipping in the ponderosa pine type with an average of 48 units of chips produced at each landing. Landing sizes were, at the largest, 215 feet by 55 feet and were about what had been predicted. The open nature of the ponderosa pine type made the landings unobtrusive. In the spruce-fir type in Colorado, only one landing was used for producing the 421 units of chips. This landing was on a hill top which was not forested. Landings as large as those in the ponderosa pine type might have an adverse esthetic impact in some areas of dense spruce-fir.

Bark disposal was probably the environmental factor of greatest concern to forest managers prior to the field test. In the ponderosa pine type, bark was spread on the landing and in the adjacent residual timber stand by a front-end loader. After the debarking-chipping operation, it was not apparent that any bark had been spread, however, and further study of the long range effects of spreading the bark was not considered necessary. In the spruce-fir type, the bark was piled adjacent to the landing where it remained until after the field test, when it was spread on the landing with no apparent detrimental effect.

ECONOMIC ANALYSIS

Actual chip production averaged only 15 bone dry units per day over the 63 working day period for the debarker-chipper. At this rate, the cost of chipping alone would be about $38 per unit. However, the 63 day period included much time lost to various kinds of mechanical and logistic delays, some of which should be eliminated or reduced in an ongoing operation.

Excluding all delays, production rates were 7.9 bone dry units per net operating hour in Arizona and 7.6 units in Colorado (points A and B, respectively fig. 1). Maximum production was only about two-thirds of what had been predicted in the analysis done before the demonstation test. The debarking-chipping costs per bone dry unit for net production rates are shown in figure 2.

The abscissa scale of figure 2 is in terms of R and the different curves represent four combinations of the remaining variables as shown below:

Curve	T	U	M
Arizona (actual)	0.54	48	1.08
Colorado (actual)	0.54	-	None
Arizona (potential)	0.80	48	0.40
Colorado (potential)	0.80	-	None

For each curve it was assumed H (time per day available for chipping or moving) = 7.5.

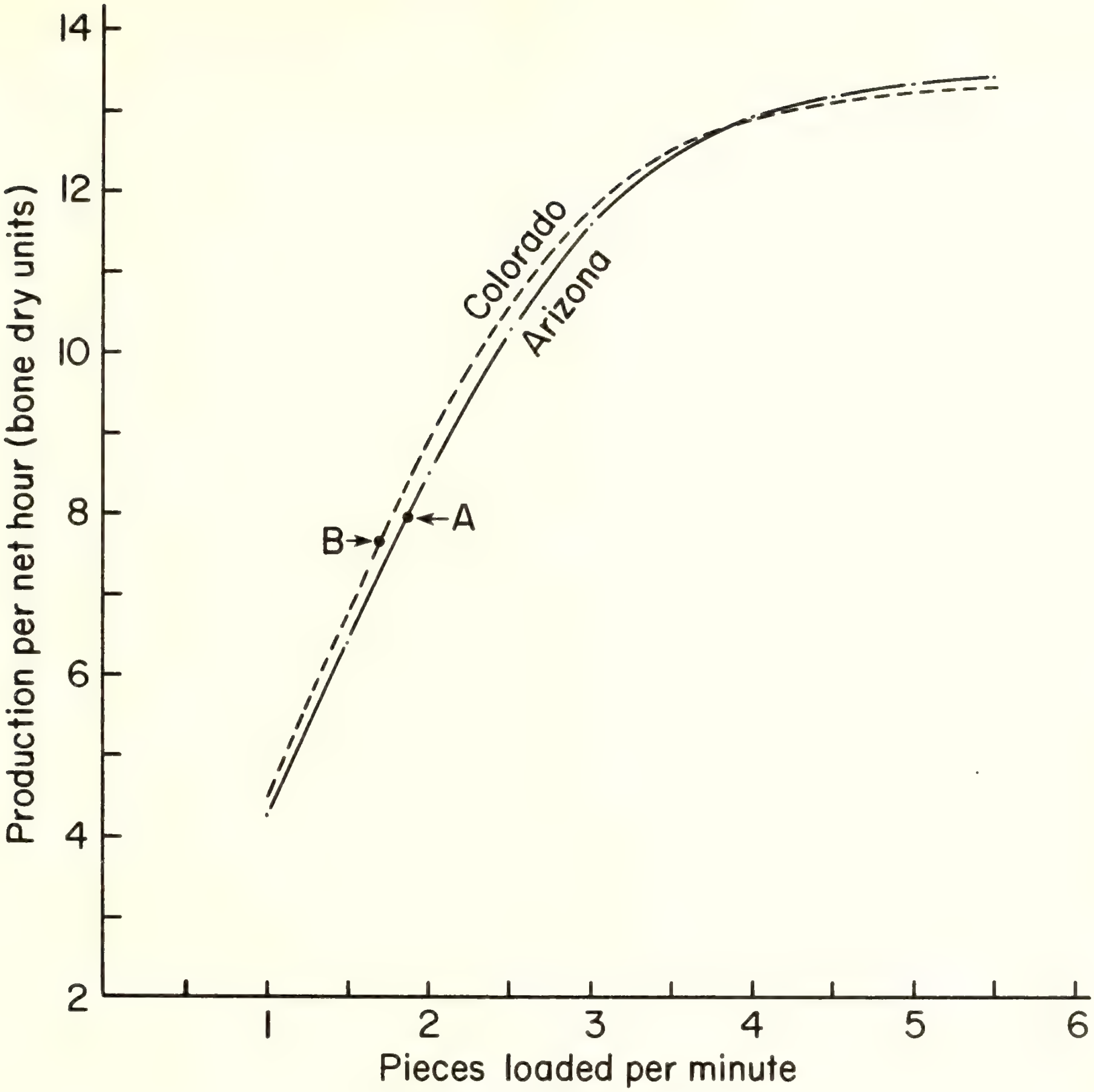

Figure 1.--Theoretical chipping rate in bone dry units per net hour at a feed rate of 85 feet per minute for actual pieces chipped.

The Arizona (actual) curve represents conditions similar to those that would have been encountered on the Arizona test area if startup problems and weather delays were eliminated. Point A on this curve represents the 7.9 bone dry units per net production hour experienced in actual operation. The Colorado (actual) curve represents conditions that would have been encountered in the Colorado test without startup and weather delays. Point B on this curve represents the 7.6 bone dry units per net production hour experienced during the field test. Moving time was not deducted since all production was at a single landing.

Curves Arizona (potential) and Colorado (potential) portray production and cost levels that would be achievable by increasing the porportion of net operating time from 54 to 80 percent and for curve Arizona (potential) decreasing the average time for moving the chipper from 65 to 24 minutes (Colorado (potential) assumes no moving). Points C and D, on these curves represent production when production per net hour is 11 bone dry units, which is probably near the maximum possible production for the size of pieces being chipped.

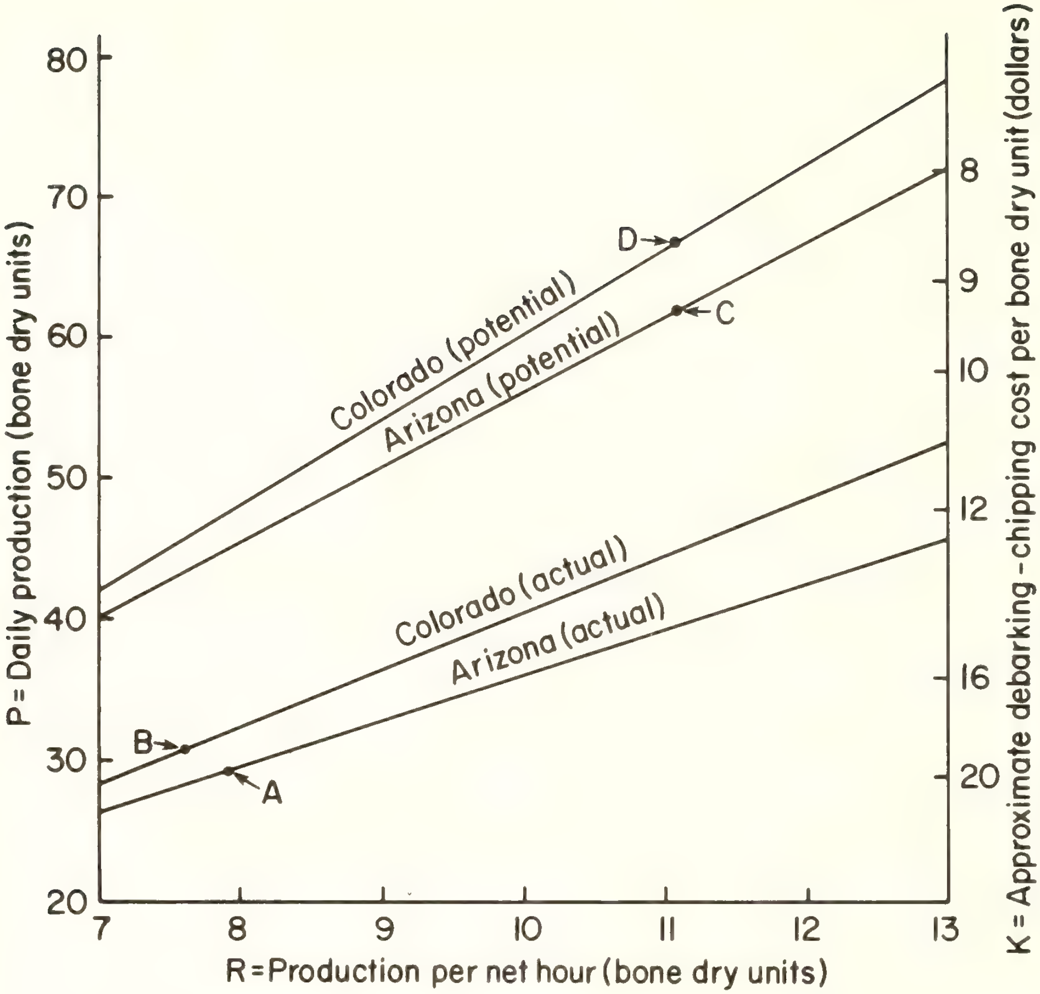

Figure 2.--Daily chip production and approximate cost by net production rate, size of log deck, proportion of available time in production, and moving time between log decks.

Daily productivity and cost are based on the following:

$$\text{Time per log deck} = \frac{U}{R\ T} + M$$

and

$$\text{Log decks per day} = \frac{H\ +}{\frac{U}{R\ T} + M}$$

Thus the equations for the two ordinate (vertical) scales of the curves in figure 2 are given by:

$$P = \left[\frac{H}{\frac{U}{R\ T} + M}\right] U \text{ or } P = \frac{HRT}{1 + \frac{MRT}{U}} \text{ and } K = \frac{572.16}{P}$$

Where: P = daily production in units of chips.

H = hours per day available for chipping and moving the machine.

R = units of chips produced per net production hour.

T = percent of time available for chipping that the machine is actually in production, expressed as a decimal.

M = moving time (in hours) between decks.

U = number of bone dry units per deck.

K = cost per bone dry unit.

572.16 = average daily cost of operating the debarker-chipper system, in dollars.

Conclusions

The conclusion we reached after this study was that in-woods debarking-chipping, at best, was only marginally competitive with producing chips from stem wood transported to the mill. We also recognized that a promising way to lower chip costs was to eliminate the requirement for debarking. There is no doubt that whole-tree chipping can deliver chips to the mill at a lower cost than in-woods debarking-chipping. Disadvantages of whole-tree chipping are: possible greater damage to the residual stand during harvesting, possible long term growth potential reduction due to nutrient depletion, and cost of bark separation if bark cannot be tolerated in processing and use of the chips for pulp or fuel.

ECONOMIC COMPARISON OF CHIPPING SYSTEMS

Cost comparisons among chipping systems are difficult because of the scarcity of data and the variation among situations encountered. The subjective comparison we developed was based on our experience of in-woods debarking-chipping of stem wood, conventional debarking-chipping of stem wood at the mill, and whole tree chipping in the woods. The cost for each function within the conventional system was assigned the index value of 1.0. A comparative index number was developed for each function in the other two chipping systems (table 1). Cost comparisons of the three systems were then developed.

The productivity of the in-woods debarking-chipping system was assumed to be equivalent to point C on figure 2. The ratio of at-plant chipping costs to in-woods debarking-chipping costs was assumed to be the same as that determined during the 1973 study. Current average costs for felling, limbing, and bucking, skidding, and loading pulpwood applied to timber sales by Forest Service Region 2 were used (United States Department of Agriculture, Forest Service, 1979). Chipping costs at a mill were estimated after consulting several sources (Bonneville Power Administration, U.S. Forest Service, Pacific Northwest Region and Pacific Northwest Region and Pacific Northwest Forest and Range Experiment Station, 1979[2/], Folkema, 1977: U.S Forest Service, North Central Forest Experiment Station, 1978). Hauling costs were assumed to be 8.8 cents per ton mile for logs. Extra handling costs were included for log handling when chipping was done at the mill. For whole tree chipping, extra costs were included for bark and wood separation (which might not be necessary depending on the use to be made of the chips). The results are graphed in figure 3.

Conclusions

For the costs used, whole tree chipping was comparable with conventional roundwood harvesting with chipping at the plant. If barky chips can be used, the bark and chip separation cost can be eliminated, making whole tree chipping even more attractive. The cost of whole tree chipping can be reduced even further if credits can be taken for removing material that would otherwise have to be piled and burned or removed in some other manner.

2/ Bonneville Power Administration Branch of Power Resources and U.S. Forest Service Pacific Northwest Region and Pacific Northwest Forest and Range Experiment Station, 1979. Progress report, feasibility of a forest residue power plant. Unpubl. Rep. 14 p + app. Bonneville Power Admn. Portland, Ore.

Table 1. Cost comparison index for harvesting/chipping systems

FUNCTION	SYSTEM		
	At-plant	In-woods	
	Debark and chip stem wood	Debark and chip stem wood	Chip whole tree
	- - - - - -cost index- - - - - -		
Fell, limb and buck	1.00	.65	0.40
Skid	1.00	1.05	1.20
Load	1.00	0.00	0.00
Chip	1.00	2.70	1.50
Haul	1.00	0.90	1.05
Extra handling	1.00	0.00	2.00

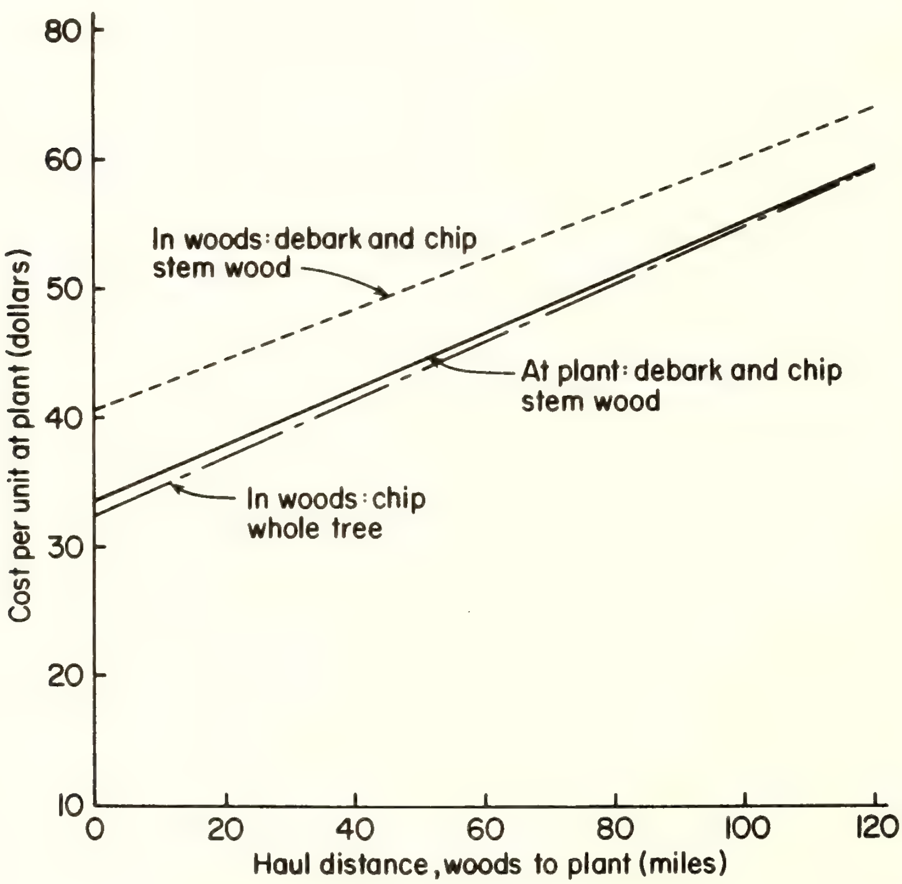

Figure 3.--Cost comparisons for harvesting/chipping systems for short haul distances.

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UTILIZATION OPPORTUNITIES

The wood processing industry has faced numerous challenges in the past, and with a combination of ingenuity, perseverance, and a little research, has surmounted difficult obstacles. A major challenge facing the industry today is the need to achieve more complete and efficient use of our available wood resource. Product, process, and market experience and research being reported in this Symposium are directed specifically toward improving the feasibility of utilizing forest residues. In the Rocky Mountain west, this places emphasis upon dead timber, and upon small stems, since these comprise the major proportion of the residue resource.

Forest residues include material that can be used for virtually every product manufactured from the so-called "merchantable" timber resource. Given favorable economic conditions, material historically considered residue is being used for lumber, house logs, treated wood products, and for chip and fiber-based products. Recent concerns about high energy costs and fuel shortages have renewed interest in wood as a fuel. Processing characteristics and methods frequently differ from those used for commercial timber, however, leading to a need for new information and new technology.

Research and industrial experience being reported here deals with the recovery and use of residues in general, but emphasizes utilization of dead timber. In that regard, the Symposium serves to assemble information that can enhance utilization opportunities for dead timber, and help avoid some of the potential pitfalls in processing.

PARTICLE AND FIBER BUILDING PRODUCTS FROM RESIDUE RAW MATERIAL

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ABSTRACT

Considerable research has been conducted on the use of dead standing trees of western white pine (Pinus monticola) and lodgepole pine (Pinus contorta) for use in various composition board materials. Much of this raw material is normally unacceptable for solid wood products such as lumber and plywood. It can, however, constitute an important resource for wood construction materials in the form of composition materials. Composition panel materials include underlayment grade particleboard, furniture grade particleboard, structural flakeboard, hardboard, and medium density fiberboard. The material would also be acceptable as core material for composites made of particleboard cores and veneer faces. Experimental boards have been made which meet the commercial standards for the above named composition panel materials. Economic analyses have shown that there are no particular penalties in cost associated with the use of the dead material in comparison with standard green material once the raw material has been delivered to the plant site. The residue raw material could also be used in molded products and lumber products of composition materials or composites.

KEYWORDS: residue utilization, building materials

INTRODUCTION

Forest residues are considered garbage by much of the forest products industry. It is difficult to use much of this raw material in lumber and plywood manufacture; however, compared to the raw material used for much of the composition materials industry, forest residues can be a quality raw material.

Using forest residues only for composition materials probably is not an appropriate path to follow in developing this resource. Lumber, veneer, house log, and other high value products should be made with whatever raw material can be "creamed" from the harvest for these products. Then, producing composition material for use in building or furniture becomes a distinct possibility as part of an integrated forest products complex.

This paper will cover definitions of the composition and composite materials, provide a brief history of this segment of the forest products industry, describe types of building materials now being produced or possible to produce, discuss recent developments, and--finally--present the role of forest residue raw material.

DEFINITIONS

Definitions of the various wood composition materials can be quite confusing. The definition I've developed for composition materials covers all types of fiberboard, particleboard, flakeboard, mineral bonded products, and molded materials. The term covers all products made with various types of wood particles including fiber. A full discussion on these definitions can be found in the first book cited at the conclusion of this paper.

In the wood industry, composites have come to mean a material made of particleboard and wood veneer. The common product at present is a panel with veneer faces and a particleboard core. What I call a "true" composite is made of dissimilar materials, e.g., metal-faced plywood.

BRIEF HISTORY

Wood composition materials are a development of the twentieth century. Wet process insulation board and mineral bonded products were developed in 1914. The first American particleboard plant was in operation in the 1930's. The major development of this industry has taken place since World War II, as has the development of extruded particleboard. Dry process hardboard arrived in the late 1940's. The manufacture of molded products started about this time as well. Medium density fiberboard production started in the mid 1960's. Oriented flakeboard arrived in the 1970's, as did the first wood panel composites.

Figure 1 is a graph of the production of insulation board, particleboard, and hardboard since 1960. Notable increases in production are apparent. An interesting relationship is the weight of wood going into these products and medium density fiberboard as compared to softwood plywood. Taking into account the various thicknesses and board densities, approximately 90 percent as much wood ends up in composition materials as in softwood plywood.

The major point is that the composition materials industry is well developed, having a solid scientific, technical, and experienced manufacturing base which can provide the background data for any new plant or development. It is not a new industry as some not in close contact with the industry might surmise. It is a viable, well established segment of the forest products industry.

An interesting observation is that the Inland Empire and Northern Rocky Mountain area has more types of composition and composite plants than any other part of the country. The first waferboard plant (now obsolete and closed) was located at Dover, Idaho. Other plants are wet process hardboard and insulation board at

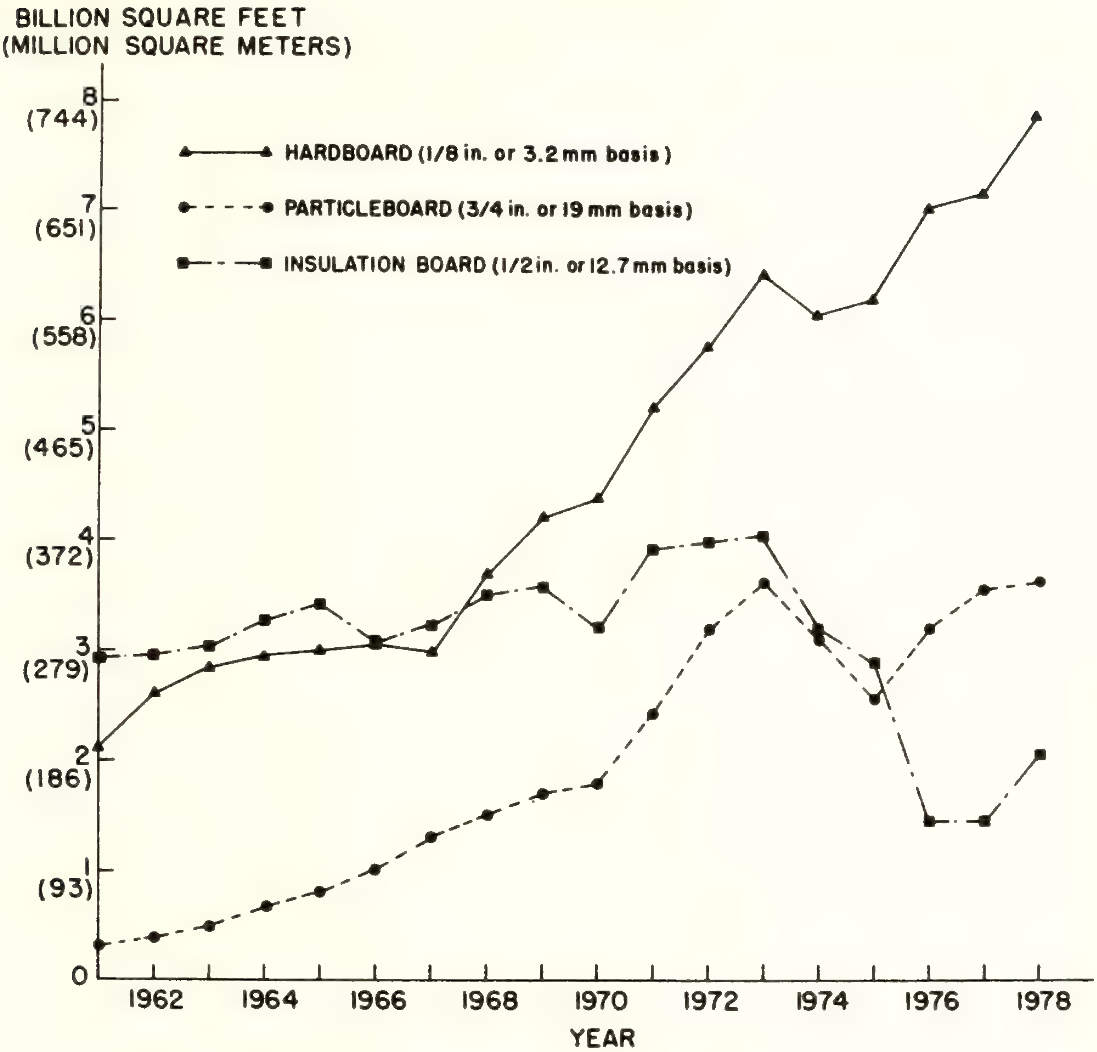

Figure 1.--Production of three different composition board products from 1960-1978.

Pilot Rock, Oregon; medium density fiberboard at Kalispell, Montana; underlayment particleboard at Post Falls, Idaho; industrial particleboard at LaGrande, Oregon, and Missoula, Montana; composite panel with oriented flake core at Lewiston, Idaho; and composite panel with randomly layed up core at Baker, Oregon. Thus intensive in-region experience has already taken place in the area of composition and composite panel manufacture.

TYPES OF BUILDING MATERIALS

The composition panel materials already mentioned are being used extensively for sheathing, siding, wall paneling, floor underlayment, furniture, cabinets, and mobile home decks. These panels include hardboard, insulation board, mineral bonded board, underlayment and industrial particleboard, medium density fiberboard, thin particleboard and fiberboard used for wall paneling, flakeboards made with relatively thin flakes for industrial and construction uses, and flakeboards with specially cut thicker flakes (waferboard) for sheathing and other construction uses.

Wood panel composites, as mentioned previously, are being made with veneer faces and two different types of particleboard core. However, veneer or lowgrade particleboard core could be used as the core with flake, fiber, or other particles for the faces of such composites. All composite products have the advantage of lower weight and less adhesive use as compared to an all composition panel material.

True panel composites are not new. They include plywood and composition panels overlayed with resin-impregnated paper sheets, plastics, fiberglass and metal. A recent and interesting new possibility is the use of basalt fiber as part of the composite. Developments at Washington State University have made possible the production of strong fiber from the vast amounts of raw material available.

Lumber products have been produced and used in demonstration projects. These include flakeboards, composites with veneer on the lumber faces and particleboard in the core, and composites with veneer strips on the edges of a particleboard core.

For a number of years, shaped and engineered composition materials have been manufactured, including molded products for doorskins, window sills, door jambs, and other building parts. Molded particleboard pallets are being manufactured in Europe and the United States. Corrugated panels have already been invented. Such engineered panels provide high strength materials while conserving raw material because of the panel design. Flakeboard is a distinct possibility for use in engineering products such as wood I-beams. Flakeboard can serve as an excellent web material in these products. Composition materials may well be developed for use in trusses and laminated beams.

Many engineered products are made possible by engineering materials with various shapes. Superior strengths and other properties can be developed by use of the right combinations of wood particles, appropriate arrangement of the particles within the material, the use of the right adhesive and adhesive additive type, the selection of the appropriate material density, incorporation of additives for preservative treatment and fire retardancy, and using other materials in combination with the wood.

RECENT DEVELOPMENTS

Some of the more recent developments such as composites, paneling core, and pallets have already been covered. It is important to recognize, however, that the production of these products already is being expanded. Waferboard, while an old product, is enjoying a tremendous new expansion.

Particleboard overlayed with resin-impregnated paper is being used for concrete form board. Sizes much larger than conventional plyform are available, thus reducing the flashing marks in the concrete made at the joints between panels. On large jobs, the use of the large panels has the possibility of reducing the costs as fewer panels have to be handled.

Particleboard shelving has become a major item over the last several years. Particleboard stepping is another product now available at a much lower cost than conventional clear lumber stepping. Treatments are being developed for use as surface and edge coatings for particleboard used in building construction. The coatings prevent or reduce the pickup of water during the construction period. Thus excessive swelling of the panel is alleviated along with concomittant reduction in properties.

The industry is striving constantly for new and improved products. All such work provides a greater data base for new industry to draw upon in developing plants and products.

ROLE OF RESIDUE RAW MATERIAL

Predictions are for a strong demand for housing through the 1980's. Problems with harvesting sufficient timber for conventional lumber and plywood production are well known. However, very high levels of forest residues are available for use. To meet the demand for construction and other wood materials, it will be absolutely necessary to utilize more of the forest residue material. In order to do this, composition and composite materials will have to be a major part of the product mix simply because of the irregular or small shapes of the raw material available.

The role of residue raw material, therefore, will be extremely significant because of its availability and relative suitability as a raw material for composition materials. Furthermore, good or superior panel, lumber-type, and shaped materials can be manufactured.

Cooperative research on the use of the dead tree resource for composition board has been conducted by Washington State University and the following USDA Forest Service Stations: Pacific Northwest Forest and Range Experiment Station, Rocky Mountain Forest and Range Experiment Station, and the Intermountain Forest and Range Experiment Station. The research has shown that good underlayment and industrial particleboards, hardboards, medium density fiberboard, and flakeboard can be made from the dead standing resource of western white pine (*Pinus monticola*) and lodgepole pine (*Pinus contorta*). Complete information on this research and development has been reported in the second and third publications cited.

The major conclusion of the research was that the dead classes of white pine and lodgepole pine could be used effectively for various types of composition boards. Some refinements of the board-producing parameters are needed to optimize commercial board formulations, but these would be minor and reasonable changes according to today's board technology. Of the particles studied, hammermilled, ring-cut flakes, atmospheric-and pressure-refined fiber appeared to be best. Structural flakeboards of drum-cut flakes had low internal bond, indicating gluing problems with flakes cut from dry dead material. Further research on this type of board is underway, and is directed towards handling this problem.

Several conclusions were reached on boards evaluated for internal bond, modulus of rupture and modulus of elasticity, 24-hour water-soak responses, and linear expansion. Differences in internal bond occurred between live and dead classes in some cases, whereas no great differences were observed otherwise. Phenolic bonded particleboards of hammermilled particles made from dead lodgepole pine were better than those from live lodgepole. Fiberboards (pressure-refined fiber) of live material bonded with urea were better than those of dead material. Flakeboards of drum-cut flakes from live and dead material were quite low in internal bond. Milling the wide flakes from live material into narrow widths resulted in an approximate doubling of the internal bond.

With a few exceptions, modulus of elasticity was about the same for each species when comparable particles were used. Particleboards of hammermilled particles made of live material of both species were better than those of dead material because of the better particle geometry. Fiberboards of live white pine exhibited

moduli of elasticities that were slightly greater than those of dead classes. Flakeboards had the highest modulus of elasticity values, with live class material higher in stiffness than the dead classes.

Boards from live and dead classes for all these board types were about the same in 24-hour water soak responses.

In linear expansion, more moisture was absorbed than expected, which seems to be a species effect. Some unidentified mold formed on the urea-bonded fiberboards. Particleboards of hammermilled particles from live material were lower in linear expansion, and therefore, were better than those from dead material. This was due to the better particle geometry of the live material. Fiberboards of dead white pine were higher in linear expansions than those from live, while the reverse was true with lodgepole. Flakeboards were very low in linear expansion and were best in this property.

Standing dead white pine and lodgepole pine as sampled for this study retained to a remarkable degree their original properties important for use in composition board products--even after many years of standing dead. The types of deterioration which prevent its use in lumber and plywood--such as deep checking, widespread sapstain, and pockets of decay--did not have appreciable adverse effects on those aspects of suitability for composition board considered in this phase of the study.

Sapstain, which was widespread, apparently has little effect on milling properties or resin compatibility.

Actual decay, in the form of saprot or heartrot, was present in such small amounts (overall much less than one percent) that it has negligible effect when uniformly dispersed through the furnish, as occurs automatically in board manufacture.

Deep checking caused some additional surface to be exposed to weathering and oxidation, but the depth of the surface effects is so slight that nearly all of the new surface formed in any of the particle-generating processes is new, unweathered surface.

The measurable chemical properties (pH and buffering capacity) of the dead wood important to resin compatibility, particularly with urea resin, are essentially unchanged from the live wood and are in a range easily accommodated by present practices in the industry.

The amounts of usable particle furnish that can be made by the five particle-making methods studied are high and not appreciably different from the amounts made from live trees of the same species.

A wide spectrum of particles, capable of meeting the needs of many different types of board plants, ranging from crude hammermilled particles through sophisticated pressure-refined fiber, can be generated from the dead material. Optimum particle-generating techniques were not established, and better results could be expected with such optimization. Excellent fiber of very low bulk density was produced by simple atmospheric attrition milling, and it is assumed that quality fiber could also be made at higher bulk densities.

Two aspects in which the dead material differed markedly from the live were in the amounts of bark and moisture present, both decreasing with elapsed time from death of the trees. In present composition board practice, the loss of bark would be considered an advantage. The reduced moisture content (mostly below

fiber saturation) would have important advantages in reducing transportation and drying costs and should reduce the rate of deterioration in stored logs or chips.

Moisture content had marked effect on power requirement in hammermilling of chips--the less moisture, the less power required. Power requirement was little affected by moisture in the other milling methods for which measurements were made. Because of the very short runs involved, the measured power requirements should be considered only as approximations, but the relatively low power requirement for drum-flaking could be of considerable economic significance. Also, because of the short runs, no estimate could be made of the effect of the drier dead material on knife life and required sharpening frequency.

Moisture content of the raw material also affects the geometry of particles generated by hammermilling and by drum flaking and thus can affect the mechanical properties of the boards. In drum-cut flakes, the particle geometry of flakes cut from live material can be modified after the flaking and drying operations by light attrition milling of the flakes to split them to narrower width, thus approximating the geometry of flakes made at lower moisture content, if desired. Moisture content of chips could be adjusted to optimum levels before ring-flaking or hammermilling operations if needed, but logs from drum-flaking would presumably be flaked at the moisture content as received.

Typical commercial boards of dead class material showed excellent properties in general. Underlayment boards had good properties except for excessive linear expansion in lodgepole pine. This high linear expansion over white pine, observed throughout this part of the research, was attributed to a species effect.

Furniture-core particleboards had superior properties. Door core had excellent internal bond, and 1C1 particleboard requirements were met for modulus of rupture and modulus of elasticity. However, 1C2 board requirements for bending and stiffness were not met. Linear expansion minimums were exceeded for both 1C1 and 1C2 boards, with white pine barely exceeding the minimums. (1C1 and 1C2 refer to the designations in the particleboard standard found in the last reference cited.)

Good modulus of rupture and modulus of elasticity values were observed in structural flakeboards. It was difficult to achieve internal bond values meeting the commercial standard requirements. Poorer quality flakes, due to flaking dead, dry material, apparently were responsible for the low internal bond. Because of the favorable flake geometry, linear expansion was the lowest for any type of board made.

Excellent dry process hardboards were made from both atmospheric- and pressure-refined fiber. A reduction in the 3 percent resin level used should be possible while still meeting appropriate standards.

Medium density fiberboards had good internal bond, modulus of rupture, and modulus of elasticity properties. Some problems occurred in measuring linear expansion, making it difficult to assess this property.

The important point is that appropriate standards and specifications were met for most of the various types of panels made. It was demonstrated also that bonding problems expected in working with a dead wood resource were non-existent. Thus, the dead standing tree resource--and by extrapolation, the dead and down resource--is a valuable raw material for composition materials. Some work was performed with dead and down material for lodgepole pine which provided about the same results as with the dead standing resource, thus indicating such extrapolation of the research results was reasonable.

More recent research has investigated the economics of producing the composition materials mentioned above with both standard green and dead raw material. The analyses were made based on the costs of production once the logs were received at the plant. (See the fourth source cited).

The following table provides production costs comparing boards made from the two types of raw material. The analyses called for debarking the logs and using all wood waste for fuel (table 1).

The important observation is that the production costs are about the same when using either type of raw material for any of the board products. Tradeoffs are found in particle preparation, drying, and amount of fuel available, but the various tradeoffs balance out throughout the production process.

Table 1.--Comparison of Production Costs for Various Types of Composition Boards Made from Conventional Live and Dead Tree Raw Material.

Particleboard	Plant Size (Tons)	Costs/MSF (3/4 in. basis) Conventional	Dead Tree
Underlayment	150	$120	$123
Industrial	150	159	164
Industrial	300	120	122
	Plant Size (Tons)	Costs/MSF (3/8 in. basis Conventional	Dead Tree
Flakeboard	200	$ 79	$ 78
Flakeboard	300	71	69
Fiberboard	Plant Size (Tons)	Costs/MSF Conventional	Dead Tree
		(3/4 in. basis)	
Medium-density fiberboard	150	$162	$162
Medium-density fiberboard	300	126	125
		(1/8 in. basis)	
Hardboard	224	$ 35	$ 35

CONCLUSION

More wood composition and composite materials will be needed in the immediate future. Present wood products manufacturers can stay in business or expand their business by producing some type of composition or composite material. The field is open also to new manufacturers.

Manufacturers will need some type of guarantee of the amount of raw material available as these types of plants are expensive. No one can make the investment without a supply of assured raw material. Collection or harvesting the raw materials has to be performed economically. Great efforts are underway in this area. Success will provide even greater incentive to produce composition and composite materials from forest residues.

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EXTENDED USE OF RESIDUE FOR CONVENTIONAL SOLID WOOD PRODUCTS

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ABSTRACT

There is no inherent difference between the wood from dead trees and green trees. Solid wood product studies have indicated that dead trees can be used for lumber, houselogs, and posts and poles although the amount of usable lumber is usually lower for dead trees than for green trees. Dead trees may be preferred for houselogs, posts, and poles; however, extra care is required in selecting and processing these products.

KEYWORDS: dead tree utilization, dead tree lumber, posts and poles, lodgepole pine, western white pine

INTRODUCTION

The management of timber stands, including the harvesting of trees, creates large quantities of forest residue. This residue, of all sizes and shapes, remains on the area after removal of the merchantable logs and includes branches, tops, cull and unmerchantable small trees, broken pieces, long butts, and standing and down dead trees. In the northern Rocky Mountain area, dead timber often constitutes most of the post-harvest residue. The slow rate of wood deterioration in this region allows trees killed by insects and disease to accumulate in the forest, adding to harvest waste. During the past few years, we have investigated the qualities of wood in dead trees and possibilities for utilizing it.

Our initial investigations concerned the inherent wood characteristics, chemical and mechanical, that might inhibit the use of dead trees. One study (Lieu and others 1979) indicated that for lodgepole pine (*Pinus contorta Dougl.*) and western white pine (*Pinus monticola Dougl.*) there was no difference in the quantities of cellulose, lignin, or other chemical constituents between dead and green tree wood. The ash content of the dead trees tended to be slightly greater than for green wood, but this difference was probably due to the wind-blown dust and dirt that had collected in the wood surface of the barkless trees.

Another study (Gernert and others 1979) evaluated physical characteristics, percentages of shrinkage values, and specific gravity of long-term dead, recently killed, and green western white pine. No differences were found in these variables for the three wood types studied.

A third study (Lowery and Pellerin[1]) determined the mechanical, or strength, properties of lodgepole and western white pine. Results indicated that the modulus of rupture and of elasticity for the dead and green dimension lumber were very similar; therefore, the lumber could be used interchangeably without any ill effects.

These studies showed that nothing should limit the use of dead tree wood, however, the appearance and defects of dead trees and logs may inhibit their utilization for solid wood products such as lumber, house logs, posts and poles. Available information on these products is discussed separately.

LUMBER

One of the highest-valued products from green trees is lumber, so dead trees were also evaluated for this end use. Studies have determined the quantity and quality of lumber from dead trees, and compared these values with those of green logs. Summaries of these studies follow.

Lodgepole Pine

Carr (1978)[2] and Dobie and Wright (1978) have reported the results of lumber grade-yield studies for lodgepole pine. Carr summarized investigations made on three National Forests--the Bitterroot, Gallatin, and Beaverhead, in Montana. The Bitterroot study used green and dead trees obtained from a decadent, old-growth stand. The dead trees were from a wide variety of natural mortality quality classes, from the recently dead to downed trees. Both dimension and boards were cut from the study logs.

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[1]Lowery, D. P. and R. Pellerin 1979. Evaluation of dimension lumber made from dead trees. Review draft.

[2]Carr, W. R. 1978. Comparison of lodgepole pine lumber recovery from live and dead timber. USDA For. Serv. Office Report, 19 p. Region 1, Missoula, MT.

In addition to the green control logs, the Gallatin study included green-needled trees that showed signs of medium to heavy bark beetle infestation; red-needled trees, dead less than 3 years; and trees dead longer than 3 years. Only 1-inch (2.5 cm) thick lumber was produced in this study.

The Beaverhead dead trees included a few that were red-needled and a few taken from the ground. The other trees in this category had been beetle-killed for various intervals of time.

All the study logs had a minimum small end diameter of 5.6 inches (14.2 cm) a minimum length of 8 feet (2.4 m) and were at least one-third sound. A summary of the results is shown in table 1.

The table shows that dead trees have considerable value when used in lumber production. The quality of lumber is reflected in the lumber value per thousand board feet (M bd. ft.), which ranged from $178 to $222 for the green trees and from $150 to $200 for the dead trees. Obviously, a lower quality of lumber is produced from dead tree logs. The differences between dead and green tree lumber values ranged from $16.71 in the Beaverhead study to $71.58 in the Bitterroot study.

Table 1.--Summary of the results of mill scale studies made on three national forests in Montana.

Study	Timber type	Percent dimension lumber	Value per M bd. ft. lumber tally[1]	Percent lumber recovery	Value per M bd. ft. net log Scale
Bitterroot	Live	40	$221.99	150	$332.98
	Dead	60	150.41	134	201.55
Gallatin	Live	0	261.53	121	316.45
	Dead	0	199.81	141	227.78
Beaverhead	Live	89	177.53	172	305.35
	Dead	91	161.82	150	242.73

[1]The lumber values are based on Western Wood Products Association year-end Report No. 12, 1977.

The highest values for dead wood were obtained when 1-inch thick (2.5 cm) lumber was produced (Gallatin study). The percentage of lumber recovery indicates a smaller amount of lumber was made from the dead tree logs than from the green tree logs, except for the Gallatin study. Just as the increased number of kerfs required to produce 1-inch boards reduced the percent lumber recovery in the Gallatin study, so also the increased number of defects in the dead logs reduced the percent lumber recovery in all the studies. The value per thousand net log scale indicates both the quality and quantity of lumber produced for the two log types.

Four categories of lodgepole pine trees--(1) green, (2) red-needled, with some dead more than 2 years, (3) gray with tight bark, probably dead more than 4 years, and (4) gray with loose bark, dead longer than the preceding groups--were used in a Canadian study (Dobie and Wright 1978). The results of this investigation were essentially the same as for Carr's studies (1978). A smaller quantity and lower quality of material was recovered from the dead trees than from the green trees. The study also indicated that beetle-attacked trees should be harvested prior to foliage loss, if possible. The lowest values and quantities were obtained from those trees dead the longest time.

Western White Pine

Two studies have determined the value of dead western white pine in northern Idaho (Snellgrove and Fahey 1977; Carr 1979).[3] In the first study, the trees were classified as either live, dead 1 or 2 years, dead 3 to 6 years, or dead more than 7 years. The average d.b.h. of the classes ranged from 19 to 21 inches (18.3 to 53.3 cm). All logs were processed into 4/4- and 5/4-inch (2.5 and 3.2 cm) lumber.

The study's results showed that the trees dead the longest time had the greatest loss in usable wood. The loss in volume for the different classes due to felling, handling, and transporting to and around the mill was as follows:

Quality class	Percent loss
Live	4.5
Dead 0 to 2 years	6.7
Dead 3 to 6 years	9.5
Dead 7+ years	10.8

The tops of older trees can absorb less shock, and tend to shatter when the trees are felled. In addition, smaller amounts and lower grades of lumber were obtained from dead trees (table 2).

The second white pine study (Carr 1979) had three classes of trees: (1) live; (2) probably dead less than 5 years, with 90 percent or more of the bark retained on the tree; and (3) probably dead more than 5 years, with less than 90 percent of the bark retained on the tree. All logs were at least one-third sound and were cut into 1- and 2-inch thick (2.5 and 5.1 cm) lumber.

The results, summarized in table 3, showed that older dead trees had a greater percentage of defective material (gross vs. net log scale) but that a greater percentage of lumber, based on net log scale, was recovered from these logs. However, both the value per M bd. ft. and the associated lumber quality were lower for the older wood.

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[3]Carr, W. R. 1979. Comparison of white pine lumber recovery from live and dead timber. USDA For. Serv. Office Report, 14 p. Region 1, Missoula, MT.

Table 2.--Summary of western white pine mill scale data.[1]

Mortality class	Log scale defect	Average value[2] per M bd. ft.	Average value per C ft.[3]	LUMBER GRADE RECOVERY				
				D Select & better	#1,2,3 Shop	#1,2 Common	#3 Common	#4,5 Common
	Percent	Dollars	Dollars	Percent				
Live	14	214	109	5	9	27	47	12
Dead 0-2 yrs	50	167	81	2	3	16	26	53
Dead 3-6 yrs	85	122	49	0	4	4	33	59
Dead 7+ yrs	94	95	34	0	1	1	13	85

[1]Snellgrove and Fahey 1977.
[2]Calendar year 1977 average prices.

Table 3.--Summary of western white pine mill scale data.[1]

Mortality class	Log scale		Lumber		Value per M bd. ft.[2]	LUMBER GRADE RECOVERY				
	Gross	Net	Quantity	Percent of		#3 Clear & better	Shop	#5 Common & better	Standard & better	Utility & economy
	Bd. ft.	Bd. ft.	Bd. ft.	Pct.	Dollars	Percent				
Live	51,450	41,900	54,350	130	284	13.7	9.8	61.4	12.9	2.2
Dead <5 yrs.	40,330	18,420	37,469	204	214	3.0	5.0	67.8	17.9	6.2
Dead >5 yrs.	42,910	4,980	41,682	237	152	0.4	0.4	14.7	36.3	42.2

[1]Carr 1979 (see footnote 3 in text).
[2]Calendar year 1977 average prices.

Summary

The grade yield studies indicated that dead trees can be used for lumber production. However, the lumber made from such trees is usually lower in quantity, quality and value than lumber made from comparable green trees. Differences in volume result from breakage during felling and handling operations, decay and borer damage in the sapwood, and foreign objects imbedded in the outer wood of barkless trees.

If lumber quality is to be maintained, dead trees must be salvaged before complete foliage loss. Usually the best and highest-valued boards can be cut from the clear wood immediately under the bark. This same wood is most readily attacked by decay and stain fungi and wood-boring insects. Lumber made from the inner part of the log often contains knots or other degrading features. As long as bark remains intact on dead trees, lumber quality decreases slowly; but after about 5 years bark sloughs, deep checks develop, and the rate at which quality declines will accelerate.

Quality and quantity directly affect the value of lumber cut from dead tree logs. As the time since death lengthens, the value of the lumber that could be produced decreases.

SPECIALTY PRODUCTS

One way of increasing the value of relatively low quality lumber obtained from dead tree logs is to promote its use for specialty products, such as interior paneling, picture framing, furniture and decorative moldings. These uses accentuate the differences between dead and green tree wood and emphasize the uniqueness of dead tree lumber. This approach has been used in previous years to develop markets for white pocket veneer and boards, pecky cypress, knotty pine, wormy chestnut and, most recently, gray weathered barn wood.

Recent research at the University of Idaho has concentrated on the recovery of specialty products from dead western white pine (Howe 1978; Christophersen and Howe 1979). Fourteen logs that had been in the mill yard for at least three years were cut into 8/4 and 5/4 inch (5.1 and 3.2 cm) lumber on a circular sawmill. After drying, the pieces were resawn into 7/16 inch (1.1 cm) paneling. The value of the paneling and other recoverable pieces was estimated to be considerably above that of the original dimension lumber.

HOUSE LOGS

In recent years, a large number of dead trees has been used by the log home industry, and this segment of the construction industry has grown dramatically. It has been estimated that 200 manufacturers will produce about 20,000 log homes in 1979 and about 25,000 more in 1980.

Log home producers in the Rocky Mountain States are firmly committed to using dead trees. Dead tree logs are usually relatively inexpensive, and because they

have a lower moisture content, they are lighter in weight than green tree logs. This factor makes them easier to handle with smaller, less costly equipment, and reduces their shipping cost. Logs with drying checks can be positioned in the building to minimize the effect of these openings, and preservative solutions or stains can penetrate and coat all exposed wood surfaces. In addition, structures made from dried, dead logs are more dimensionally stable than structures made from green logs, unless the green logs have been air-dried for a long time.

Most dead tree houselogs are either lodgepole or western white pine. Tree-length lodgepole pine logs are preferred because the longer lengths allow cutting to required sizes.

POSTS AND POLES

Because of their size, straightness, minimum taper, and ease of preservative treatment, green lodgepole pine trees have been preferred for fence posts, corral or fence rails and utility poles. The same products made from dead trees possess the advantage of having lower moisture contents, thereby eliminating a long air-seasoning period and reducing the need for a large inventory. The lower moisture content also indicates lighter weight, hence larger loads and easier preservative treatment.

Post and rail specifications are usually developed by the individual treating plants and depend, to a large extent, on local conditions and practices. Appearance is often the major consideration. Pole specifications are published by the American National Standards Institute (ANSI 1972), and although standards do not require the use of living trees, the occurrence and placement of defects may eliminate the use of some dead trees for poles. Preservative treatment specifications for posts and poles are published by the American Wood Preservers Association (AWPA 1977).

Posts

A recent publication (Lowery and Host 1979) reports on preservative treatments for posts and poles made from dead lodgepole pine trees. Two treating methods, steeping and pressure, were used to treat fence posts that had been dead for at least 4 years. The 85 peeled, pointed, and capped posts used in the steeping study were placed upright in a series of tanks, filled to a depth of 30 inches with a pentachlorophenol, a light crude oil solution. Six hours was the longest soak period used.

Analysis of the disks and borings taken from the treated posts indicated that none of the treatments gave the minimum retentions required by AWPA standards (0.30 pounds per cubic foot). A slight difficulty was encountered in peeling the dead tree posts. The posts often were stopped in the debarker, and when stoppages were not corrected immediately, an excessive amount of wood was removed. The surfaces of the dead tree posts were also rougher than the surfaces of posts from green trees.

The pressure treating study used 39 posts. These posts were subjected to an initial 30 minute vacuum period followed by a pressure period of either 15, 30, or 45 minutes. (In contrast, the pressure period used for green tree posts is 3 hours.)

An unheated water solution, 1.50 to 1.75 percent fluorchrome arsenate phenol, type B (Osmosalts), was the preservative used.

Preservative retention tests performed on samples cut from the posts showed that all posts had retentions in excess of the 0.4 pounds per cubic foot required.

Poles

A recent survey of lodgepole pine in southeastern Idaho indicated that many of the dead trees in that area were suitable for powerpoles (Tegethoff, Hinds and Eslyn 1977). Of 217 pole-size trees on 46 plots, 165 were dead and about 38 percent (63) of the dead trees yielded poles that satisfied the ANSI pole standard. The most common defect was basal decay, and for many of the dead tree poles this defect had to be eliminated by long butting.

The preservative treatment of poles made from dead lodgepole pine trees has also been reported (Lowery and Host 1979). Thirty poles were randomly assigned to one of six treatment schedules:

1. Six-hour hot bath followed by a 12-hour cold bath
2. Four-hour hot bath followed by a 6-hour cold bath
3. Two-hour hot bath followed by a 6-hour cold bath
4. Nine-hour cold soak
5. Six-hour cold soak
6. Four-hour cold soak

In contrast, the commercial schedule for green poles uses a 6-hour hot bath followed by a 6-hour cold bath. The treating solution was a 5.1 percent pentachlorophenol in a heavy oil carrier.

Measurements showed that only one pole received less than the minimum required preservative penetration of 0.75 inch. All poles, except those given a 4-hour cold soak, met the 85 percent penetration of the sapwood requirement. Preservative retention measurements showed all the study poles treated by the hot and cold bath method exceeded the specification requirement of one pound of dry pentachlorophenol in the outer 0.50 inch. However, none of the poles treated by the cold soak method retained this much preservative.

SUMMARY

Investigations have shown that there is no inherent difference between dead and green tree wood. Dead trees and logs can and are used to produce solid wood products such as lumber, house logs and posts and poles.

Grade-yield studies have shown that the lumber recovered from dead tree logs is lower in value, quality and quantity than lumber produced from comparable green tree logs. Furthermore, the longer the time interval between death and utilization, the lower the value of the material recovered. The manufacture of specialty products is one way of enhancing the value of dead tree lumber.

House logs, posts, rails and poles are other potential uses for dead trees. Dead lodgepole pine trees are preferred by many Rocky Mountain log home manufacturers. Posts and poles made from dead trees can often be treated with a preservative immediately, without a long air-seasoning period, and shorter treating schedules can be used to treat these products.

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PRACTICAL CONSIDERATIONS IN USING LOW QUALITY WOOD IN LUMBER, SPECIALTIES, AND PLYWOODS

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ABSTRACT

The initial practical consideration in using low quality wood is how we view it. Beyond this psychological point, very real problems do exist. This discussion examines some of the uses of low quality wood. The solid wood product families examined include composites, plywood, lumber, laminated lumber, and cedar products.

KEYWORDS: residue utilization, wood residues, wood products

Earlier presentations in this volume have discussed the opportunities for utilizing residue. This paper will deal with "Practical Considerations in the Utilization of Low-Quality Wood." Webster's Dictionary shows about eight definitions for the word "practical," as well as reference to the word "practicable." Practicable was said to be "used of something that has not yet been developed or tried, but appears likely." Perhaps we should say that much of what has been discussed here should be labeled practicable, that is it appears possible, but has not yet been tried.

But, since we are dealing with practical considerations, we should define the word. "Practical" is defined as "obtained through practice, workable and useful, utilitarian, experienced from actual practice," and so forth. The panel discussion on which this paper is based moved from the opportunities of the practicable to the problems of the practical.

A first practical consideration in using low-quality wood is in the description of our raw material. Elsewhere in our program we have been referring to residues. Now we are using the words low-quality. Unfortunately, it is true that much or most residue type material is not the best. But with that admission, I would like to express the view that part of our practical problem may be our label.

I believe that if the residue resource is examined, a range of quality can be found which straddles at least partially the range of more "normal" wood. For example, I suspect that some dead timber is better than some live timber; some residue is superior in size class to some of the so-called merchantable material; and some residue has higher intrinsic wood value than some merchantable timber (such as pine versus hemlock).

I want to cover here some of the experiences at Potlatch Corporation1/ with so-called low quality wood in several product lines: cedar products, lumber, laminated lumber, and plywoods.

CEDAR PRODUCTS

This is probably the oldest product line based on a raw material that is traditionally a residue in Northern Idaho and surrounding areas. Several decades ago, split cedar products were mostly produced by individuals or families living and working in the forest. The raw material was often free, but converting it to saleable product was a business with the most basic practical consideration - staying alive under dangerous working conditions and making ends meet by hard and long hours.

Today Potlatch operates two cedar products plants as a part of integrated logging and milling operations. New problems arise although others may be solved. The variability of quality in defective cedar is surprising. Although our plant specs will allow a minimum log length of only 6½ feet, handling such short pieces out of the forest is awkward. Without a system for working out sawlogs from material delivered to a cedar products plant, one must guard against a downgrading of higher grade material into a longer piece of part-low-grade cedar products log. In other words, the move towards higher volume utilization can affect quality utilization. Another problem from such operations, which reduce forest residues, is the manufacturing waste factor. Two-thirds of the gross weight of delivered wood can become scrap. Accumulated at a mill, the resulting residue may be a bigger problem than if dispersed in the forest. Improving fuel markets is an answer to this situation, however.

LUMBER

I'm sure that most Rocky Mountain area sawmills are now using some logs today that previously would have been considered residue. Other speakers have cited this.

Species is a primary factor influencing the type of problems which enter the picture regarding using residue or low-grade logs for lumber. In the pines, which are typically cut to boards, checks, worm holes, and blue stain are common characteristics of the lumber output. These affect the basic grade of the product, usually negatively. Another problem is variable moisture content, which follows through in kiln drying as overdried lumber. A significant dollar loss in surfacing due to overdrying higher grade boards is well established in forestry literature.

1/ The use of trade, firm, or corporation names does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

In true firs, we find incipient and advanced decay to be the principal problem in lower grade logs. Not only is lumber grade and value lowered, there can be a breakage problem in handling, which slows production. Such pieces are preferably sent straight to the chipper, but can't always be diverted.

Douglas-fir presents relatively fewer problems in the final product, once the logs are sawn. Inherent crook in the tree is a culprit in the woods which can create low quality sawlogs. If the crooked portions aren't culled as residue, the logger may be penalized for the scale loss, and mill production can be slowed.

LAMINATED LUMBER

Here is an area where one can effectively upgrade some lumber which otherwise might be put to a lower use. It is accomplished by combining three or more pieces of varying appearance quality levels into one piece which is used according to its outer or face grade. Hoards or dimension comprised of sound solid wood can be used as center and back laminations, where visual properties can essentially be ignored. For example, knotholes are structurally equivalent to sound knots of the same size, lower value species can be used with facings of premium woods, and splits, wormholes, and other slight imperfections become relatively unimportant. Low moisture content from overdrying can be beneficial in processing and in-place product serviceability.

PLYWOODS

The plywood business has been a good one for a number of years. "Sheathing" used to mean boards, but now, as most everyone knows, it means 4x8 - CDX, or plywood.

Low quality does not present isolated problems in making plywood; essentially, it is unacceptable. The process of making conventional plywood is so standardized and streamlined that standardized raw material becomes essential. Try to run a 6-foot bolt into an 8-foot line, or put a soft-centered overmature white fir in a lathe, and everything stops. A 6-inch diameter log slows up a headrig, but is worse on a 5½-inch lathe chuck.

Potlatch faced the practical problem of using lower quality raw material, in its true sense, with our composite plywood we call "Plystran." We wanted to make more plywood without using more peeler quality logs. Some of the problems we faced, and solved, as we went from practicable to practical, were: dirt on "buckskins," mostly dead white pine; rot in defective logs, mostly true firs; achieving the excellent performance level of plywood from low-line wood; integrating log usage and conversion facilities with parallel pulp mill needs; smoothing out wood quality variation, ranging over a complete spectrum; and allowing for errors in the pioneer effort, since errors are inevitable when innovating.

Without explaining here how all these were accomplised, the conditions were: the market for the product existed, the technology was mostly available or seemed close at hand, and management was willing to take some risks. With a lot of effort by many people, success was achieved.

Using low grade wood is not done through miracles, but with the classic ingredients of most achievements: hard work, economic reality, and well-defined goals.

UTILIZING RESIDUE MATERIAL IN PULPING

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Champion International Corporation

ABSTRACT

The pulp raw material shortage in 1973 and 1974 provided incentives for using whole tree chips at a number of pulp mills in the United States. Since 1974 pulp raw materials supplies have returned to more acceptable levels. As a result, whole tree chips are being used only on a limited basis. However, energy shortages during recent years have provided incentives for the utilization of whole tree chips. Currently, projects are underway in Montana, Idaho and Washington which will increase the demand for waste fuel.

KEYWORDS: residue utilization, pulping

The pulp raw material shortage in 1973 and 1974 provided incentives for using whole tree chips for papermaking at a number of pulp mills in the United States, particularly in the South. During 1973 and 1974, the Missoula pulp and paper mill manufactured chips from dead, dying, down, diseased and defective (5D) roundwood but did not utilize whole tree chips. Since 1974 pulp raw material supplies have returned to more acceptable levels. As a result, whole tree chips are being used only on a limited basis in some parts of the country.

With the 1973-74 experience for justification, the industry, along with land management agencies, educators and equipment suppliers, have defined problems associated with the use of whole tree chips, developed solutions to many of these problems, and continued to use whole tree chips in pulp and papermaking on a limited basis.

Due to continued strength in export requirements for chips and paper demand, coupled with a poor lumber market, we are again into a fiber supply shortage for pulp and papermaking. Therefore, it is reasonable to assume that substantial quantities of whole tree chips will again be used during the next two years by pulp and papermakers throughout the United States.

Benefits from whole tree chips include increased fiber utilization, increased landowner acceptance of harvesting, reduction of site preparation costs, and reduced hazard reduction costs and disturbance to top soil.

Problems in pulp and paper manufacture with whole tree chips include abnormal wear on mill processing equipment from sand and grit, rapid deterioration of whole tree chips in storage, increased fire hazard in chip piles, increased calcium scaling in digestors and evaporators, increased cooking time and alkali consumption, increased bleach consumption, digestor feeding problems, and low chip yields.

Although the list of problems is long, considerable progress has been made in solving these problems. Processes which have been developed for upgrading whole tree chips include bark separation, chip screening and washing systems, Morbark1/ dual-spout chipper, Morbark class "A" fiber system, and whole tree forwarding to eliminate impacted grit.

With expansion of Champion International's Missoula pulp and paper mill, we are rapidly approaching a shortage of sawmill residuals in the inland area.

Our expansion alone increases the demand for chips by 270 thousand bone dry units (MBDUs) or 293 thousand metric tons per year (22,000 truckloads), fines by 145 MBDUs (157 thousand metric ton) per year (12,000 truckloads) (fines include sawdust, shavings and chip screenings), and hogfuel by 220 thousand units per year (484 thousand cubic meters, or 16,000 truckloads).

First, let's discuss chips. Very few opportunities exist for increasing the total sawmill residual chip supply. We will take advantage of chip surplus situations by purchasing sawmill residual on short-term contracts; however, when chips are in short supply, we will use pulp logs as backup supply for our chip needs. We believe that pulp logs from our fee lands and from stumpage sales purchased from the USDA Forest Service will fill our needs and, therefore, do not anticipate creating a market for pulp logs.

We also believe that an adequate supply of 5D logs on forested lands exists within our operating circle to fill our expanded needs and, therefore, are not installing the necessary processing equipment for upgrading whole tree chips for use in the Missoula pulp mill.

In addition to chips, we use fine sawmill residuals for pulp and paper furnish. Unlike chips, many opportunities still exist for increasing the utilization of fine residuals. Fine residuals include sawdust, shavings, screenings and any other clean wood particles too small in size to meet chip specifications. Champion International's expansion was broken into two phases. Phase I came on line in May of 1978, increasing our use of fine residuals from 30 MBDUs (over 32 thousand metric tons) per year to our current usage of approximately 80 MBDUs (86 thousand metric tons) per year. Phase II of the expansion included the new paper machine. Increased washing and other related equipment are necessary to supply the new paper machine with pulp. After the completion of Phase II, we will be using 175 MBDUs (190 thousand metric tons) of fine residuals per year, more than double our current usage. Our projections indicate that this expansion will utilize most of the remaining fine residuals available from sawmill and plywood plants in Montana.

1/ The use of trade, firm, or corporation names does not constitute an official endorsement of, or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

The production of energy from wood fiber holds the greatest promise for utilization of whole tree chips in the Intermountain Region. Currently projects have been announced in Montana, northern Idaho and eastern Washington which will increase the demand of wood fiber for fuel by 1.3 million tons (1.2 thousand cubic meters) per year.

Champion's Phase II includes the installation of a new hogfuel boiler which increases Champion's Missoula hogfuel needs from 180 thousand (396 thousand cubic meters) units per year to 400 thousand (880 thousand cubic meters) units per year. Champion currently burns hogfuel at the pulp and paper mill, the Missoula sawmill, and Bonner plywood plant and sawmill.

In addition to our increased needs, Washington Water and Power Company has decided to proceed with development of a 40,000 kilowatt, $46.7 million steam electric generating plant fired by hogfuel. Newspaper reports say that this plant could be operating near Kettle Falls, Washington by mid-1982. The project is subject to procurement of fuel contracts and state licensing. This plant is estimated to require about 500 thousand tons, (453 thousand metric tons or 278 thousand units) of hogfuel annually. This is the first of possibly five such plants to be located throughout northern Idaho, eastern Washington, and northwestern Montana according to various news reports.

In addition, Potlatch plans to complete installation of a new hogfuel boiler by 1981.

Most of this increased requirement will be supplied by sawmills and plywood plants; however, current economics indicate that whole tree chips from thinning residuals, log yard cleanup, and road right-of-way clearing slash will compete for a limited amount of this supply. Due to some rather encouraging results from trial chipping runs on thinning residuals, Champion plans to use a limited volume of whole tree chips as furnish for their new waste fuel boiler at Missoula.

In summary, whole tree chips have been and are curently being used for the production of pulp and paper. Locally the increased demand for new energy sources will result in the utilization of whole tree chips by Champion's pulp and paper mill.

PROBLEMS IN PROCESSING LOW QUALITY LOGS

Remington Kohrt

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ABSTRACT

The sawmilling of low quality logs, often old and dead, is usually more difficult than for green, high quality logs. Machinery and processes can be adapted to accommodate low quality material efficiently, but the resulting products must be saleable. The challenge of sawing lumber from low quality logs becomes a problem of raw materials, regulations, agencies, public needs, costs, and politics.

KEYWORDS: sawmilling, residue utilization

After the first charge of old and dead logs goes through the typical sawmill, the normal question asked is, "Did she slip, did she trip, did she fall, or who pushed her?". With a forestry/logging background at the Mt. Hood and Targhee National Forests, I'm a great one to be telling you sage souls how it is to saw lumber from low quality logs. So as not to mislead you, it works this way: an efficient sawmill can manufacture low quality lumber from low quality logs efficiently. Now that I've established my credibility by telling you nothing new, I'm going to rail away at you, a captive audience. As a captive audience, you are no different than the typical sawmill, having to accept whatever is delivered to you.

The great American forest dream is one of many facets: dedicated professional foresters managing boundless forests mature and ready for harvest; eager loggers with saws in hand who leave no mark on the forest; efficient sawmills that cut endless quality products from cull logs; a happy, consuming public with money in the bank; a resource aware citizenry that feeds confused bureaucrats correct answers to short-term political questions; and a great future for all forever.

In order to place sawmilling in proper prospective, let's examine this great American dream:

The dedicated pros - If you go by their offices at 7:00 a.m. and come home at 5:00 p.m. you miss them. As dedicated public servants they get more pay,

more security and more benefits than any segment of the population, for less production than you can tolerate in any sawmill. They are a curious blend of good guys, bad guys, professionals, specialists and pseudopoliticians. They generally know what to do, but don't have the fortitude to do it. The result is wheel spinning, whereby procedures become more important than results.

The boundless forests - These great expanses of forests are either overused, multiply used, or unused. In any regard, they usually are undermanaged, overaged, diseased, inaccessible, and resemble grandmother's apple barrel where a rotten apple is available anytime but a good one must wait until "someday."

The eager logger - He is generally a nice guy who was too proud or too ignorant to find the gravy train somewhere, so he had to go to work. Where else could you work on borrowed money, broken equipment, and have the entire population as your absentee boss?

The consuming public - This is all of us. We want more for less, sooner than later, faster than slower and above all less government, providing you cut the other guys service, not mine. We do, however, have the same basic needs as all people do - food fiber, shelter, education, health care, and job opportunities.

Resource-aware citizens - We all read the newspaper, so we're eminently prepared to respond to agency and legislative requests for opinions concerning natural resource questions. We usually elect political representatives that promise to fulfill our desires in the short term, and "short sheet" us in the long term. You can't really blame the politician, he's human too. In meeting our demand he gives us the old pitch "Give me your hat and I'll show you a trick!", and he generally does.

The future - This a place in time we are all trying to reach with our shirt, shorts, and shoes intact. Hopefully we can use our natural resources in a prudent manner such that our citizens can have their commodity needs and amenity desires fulfilled over the long term. We know the renewable resources such as timber, water, wildlife, and forage can be enhanced as they are used. Resources will contribute to society to the extent the public understands how they provide.

This leaves the sawmill, an integral part of the sequence of processing trees to solid wood lumber products. Too often people in the academic and government worlds suspect that behind the grease, sawdust, and mechanical wizardry of a modern sawmill lurks the evasive solution to old and dead forests, shortages of petrochemicals and the national debt. Folks, it just ain't so!

The sawmill is usually a steel, concrete, and wooden complex of expensive permanence. It neither controls the raw materials delivered to it nor the demands for or the prices of the finished products it produces. The sawmill, then, is a functional tool that can be changed or adapted, but by itself is really a pass-through process.

The sawmill's problems with old and dead material begin in the log yard. The log handling process creates more than ordinary breakage. This breakage results in waste, less than optimum log lengths, and increased cleanup costs. Breakage accelerates in the debarking area also because of the brittle nature of the log. In order to get the potential lumber producing log to the mill

floor, a merchandising station is needed in the log flow system. It is a place to identify, remove and upgrade the cull or problem log. This is an expensive addition to the normal mill flow.

On the mill floor, dust from the old and dead is ever present, and a problem that must be handled. The checked nature of old and dead wood is a constant hazard to saws, saw guides and splitters. Extra caution is necessary in the feeding process so saws aren't stressed, or run off the wheel from check that runs on a bias to the sawing direction. The checked nature of old and dead logs tends to pick up dirt and small stones that are held in the cracks through the entire sawing process. Damage and wear to the mill saws and planer knives is greatly accelerated. This results in increased saw purchases, more saw changes, and pressure on the filing room. The physical problem of separating good boards from cull boards or waste is greatly increased. Since more cull boards or waste is developed, means of identifying and handling must be found. Most labor-saving sawmill options that are automatic or semi-automatic are dependent on consistent log or board quality and flow. Old and dead wood is anything but consistent, and forces more manpower and judgement opportunities onto the mill floor, hence more costs.

The stacking, drying, unstacking and planer operations all must accommodate the lower quality, more variable board. Production then is more erratic and recovery tends to concentrate in the lower grades and shorts area. This necessitates carrying a larger inventory and presents the sales people a challenge. Customers accustomed to bright stock and solid stock must be educated. This education usually works in reverse, "Sure, I'll try your stained stock, but ata reduced price." Other processes, like automatic nailing, are not compatible with check. "Pick and carry" trade sees no good in stained stock. Just imagine your wife in a supermarket where someone is attempting to sell a product that is off-color, or otherwise defective.

The success of the sawmill, then, is not only one of quality and quantity of production, but of the kind of log brought to it and the demand for the finished product. If old and dead or low quality logs are the kinds of log product brought to the mill, one can usually expect reduced production, high production costs, diminished quality and lower realizations. If these circumstances can be tolerated in a balanced operation, and profit can be shown at one or more points in the process, then the operation might be termed successful. Usually the low quality, low value lumber products can be tolerated over the short term because of innovative sales promotion, high demand for the sawmill's waste, or high prices brought about by a shortage of raw material supply. Keep in mind, however, that the sawmill can't be picked up and moved easily, raw materials can't be shipped from too great distances nor can the sawmill transform culls into ladder stock, or quality dimension lumber.

In our full-stomach society, where we all seem to have plenty, problems seem to develop in relating the forests' ability to provide the public's demand for amenities. Particularly in preservationist circles, where folks are generally articulate, dedicated, well educated and involved in government or the service professions, we have lost sight of basic issues. The living forest becomes an emotional subject of mystique. This phenomena is pushed through the political process because no one can convince the preservationist he is wrong, the average citizen is too busy working or playing to be interested, and the politician wants the majority to be happy at least until the next

election. The agency then charges forth with "responsive" timber management programs that concentrate on the politically acceptable facets of overall forest management - namely salvage sales, old or dead sales, and harvest of undersize, low value timber. The timber industry then struggles with the high cost, low quality logs that are forced upon them. At the same time, a forest in need of management sits nearby producing defect faster than useable wood, a nation is a net importer of solid wood products when it could be an exporter, and a resource-unaware public complains that things should be better. The problem is simple to understand; the solution is difficult.

Perhaps we should be asking "why" things are like they are. Why does the forest-managing agency ignore what's biologically rational and endorse wholeheartedly what is politically acceptable? Why is the general public resource unaware? Why is our political representation less than enlightened, and tuned to the short term? Why do we tolerate inflation, runaway federal spending, deficit balance of payments, low productivity, and withdrawal of our natural resource base? Why do we force forest utilization beyond the limits of economic feasibility on the one hand and ensure forest waste on adjacent areas with the other? Why is a sawmill expected to make something from nothing? Why are we less than honest with each other? Why can we answer these questions as individuals or in small groups, but fail to handle them in large groups such as this?

A biologically proper timber sale provides management opportunities for the forest, income for the owner, and access, jobs, taxes, and products for the consuming public. The current politically proper timber sale provides inadequate management opportunities, perpetual salvage costs, break-even opportunity for the land owner at best, minimum or no access, minimum jobs and taxes, deficit circumstances for the purchaser, and products for the consumer he may not want or cannot afford. Why? Why?

It is difficult being a resource-dependent sawmill in the Intermountain/ Rocky Mountain area. We are keenly aware that our future, the future of renewable resources, and the future of dependent communities (and the nation) is dependent on how well government resource managing agencies practice professional resource management. Political forestry is generally short-term expediency, or management by reaction. We are painfully aware of the difference.

The situation is similar to the circumstances that are bringing about the "Sagebrush Rebellion." That is, the responsible agencies espouse policy, politics, and pressure that responds to the beat of a too distant drummer. The individual in the agency recognizes the problem and solution, but chooses not to act. The system is too static, the security too comfortable, and the principles involved are too easily swept under the rug. Hence we are here hung up on submarginal forest residues at the same time merchantable timber burns, dies, and rots in the ever growing wilderness system.

Make no mistake about it, the forest industry is not opposed to harvesting and utilizing of forest residue. We just see the challenge as a far more all-encompassing circumstance. We would rather solve the problems of a sinking boat by plugging the large holes rather than the tiny holes. The odds of reaching shore are much better that way.

In summary, what an efficient sawmill can do is manufacture low quality lumber from low quality logs efficiently. Our objective should be to grow and utilize sound sawlogs on the maximum amount of forest land possible and adapt the sawmill to produce economic lumber products that satisfy public needs. The applied arts of economic common sense and honesty will lead us out of the woods and into the light, if we use them. This can be accomplished by enlightened effort or by economic crisis. The choice is yours.

CHEMICAL CHARACTERISTICS OF WOOD RESIDUES AND IMPLICATIONS FOR UTILIZATION

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ABSTRACT

Wood and woody residues are chemically heterogeneous substances, being composed of carbohydrates in the polymeric form of cellulose and hemicelluloses, phenyl propanoids in polymeric lignin, extractable hydrocarbons, ash, and extraneous substances. Fresh green softwoods contain about 43 percent cellulose, 28 percent hemicelluloses, 29 percent lignin, 7 percent extractives, and minor quantities of ash and extraneous material. In the Northern Rocky Mountains, where dry or cold conditions predominate, woody residues remain sound without visual signs of decomposition for many years. The chemical composition of this weathered material does not change significantly and it can be utilized like greenwood. Since wood and woody residues are heterogeneous there are two basic approaches to its chemical utilization: (1) whole wood processing and (2) separation of the heterogeneous components followed by processing. The chemical utilization of woody residues is almost limitless, the major barrier being economics rather than technology.

KEYWORDS: residue utilization, wood composition

INTRODUCTION

Forest residues generated by natural and man-made processes can be broken down into three types of tissues: 1) foliage, 2) wood, and 3) bark. Each is distinct in its chemical composition, physical structure, and physiological function in the plant. If we were capable of complete-tree harvesting and utilization, the foliage would contribute about 3-10 percent, bark 10-15 percent, and wood 70-80 percent (Hakkila 1976), each varying with species, tree age, and other factors. The proportion of these three tissues in forest residues that is available for utilization is also dependent upon the age of the residue itself. This is particularly true for foliage (Keays and Barton 1975) which dries rapidly, falls to the forest floor, and becomes part of the litter in a very short time period. The utilization of foliage can only be practical in a complete-tree harvesting system where this

tissue could be concentrated and processed immediately. Bark and wood are much slower in their rates of decomposition, and will accumulate unless disposed of by burning or some other means. Bark, however, like foliage is relatively insignificant in comparison to the quantity of wood residues available in the Northern Rocky Mountains. Commercial development of just the residual woody tissues would improve the efficiency of our forest utilization substantially.

CHEMICAL COMPOSITION

During photosynthesis plants convert light energy into chemical energy with the immediate product being sugar. This sugar is used as an energy source or can be converted to reserve food (starch), structural materials (cellulose in plant cell walls), and numerous other metabolic products (amino acids) necessary for sustaining life. Wood and woody residues are predominately cell wall tissue and are chemically heterogeneous, being composed of carbohydrates in the polymeric form of cellulose and hemicelluloses, phenyl propanoids polymerized in lignin, and also some hydrocarbons, ash, and extraneous substances (Browning 1963).

The quantity of each component varies with plant species, but in general softwoods contain about 43 percent cellulose, 28 percent hemicelluloses, 29 percent lignin, 7 percent extractives, and minor quantities of ash and extraneous substances.

Fresh or newly generated wood residues are chemically the same as the green wood in a freshly harvested tree. If these residues are left for long periods they will eventually be broken down and decomposed by microorganisms, fungi, insects, etc., causing changes in the chemical composition. In the Northern Rocky Mountains where dry or cold conditions prevail throughout much of the year, decomposition is often quite slow. Therefore, wood residues may remain sound without significant visual changes for many years, but it is possible that important chemical changes could occur. To determine the effect of long exposure time on wood residues, chemical analyses were conducted to determine the extractive content, cell wall composition and combustion characteristics of green and dead (down and standing) lodgepole pine and western white pine. Except for minor variations (see table 1), the sound dead and green wood of a species are chemically comparable even after extensive exposure of the dead wood to natural forest conditions. The dead wood residues can be used as a substitute for live timber in the production of fuels and chemicals (Lieu and others 1979).

UTILIZATION POTENTIALS

Traditionally, wood has been used for structural materials, fiber, and an energy source by direct combustion, all requiring minimal chemical modifications prior to use. For many years chemists have recognized the chemical potential of cellulosic substances which could be converted to a variety of chemicals including foods, with appropriate technology.

In recent years as the cost and our dependence on foreign oil have increased, scientists and engineers have begun to investigate alternative sources of energy. Since cellulose is the most abundant organic substance on earth and because it is renewable through photosynthesis, considerable research is being directed toward using plant biomass (predominately cellulosics) as a source of energy. In addition to its energy uses, petroleum is the foundation for the industrial production of petrochemicals, many of which could be supplemented or replaced by chemicals derived from plant sources. This has renewed the interest in converting wood or cellulose and other plant substances into fuels and chemicals.

Table 1.--Summary of the chemical characteristics of live and dead wood from lodgepole and western white pine.

Characteristics	Lodgepole pine		Western white pine	
	Green	Dead3/	Green	Dead
Specific gravity	0.367	0.367	0.442	0.366
Extractives1/				
Ether	0.61	0.25	1.21	1.28
Benzene:alcohol (2:1 by vol.)	2.23	1.35	3.62	3.08
Hot water	2.71	3.72	3.26	3.88
1% NaOH	11.22	14.30	10.81	12.49
Cell wall component1/				
Alpha-cellulose	43.59	44.49	42.81	40.84
Hemicelluloses	32.72	31.27	33.05	33.05
Klason lignin	26.70	27.21	26.90	27.32
Combustion				
Heating value2/	19.95	19.77	20.05	19.96
Yield of char %	29.82	29.08	28.54	27.96
Ash %	0.35	0.51	0.33	0.28

1/Values shown are percentages.
2/mJ/kg (Megajoules per kilogram), heat of combustion.
3/Averaged for down and standing.

Since wood residues are chemically heterogeneous there are two basic approaches to utilizing this material: 1) whole wood processing or 2) separation of the components followed by processing. In general, when wood is used for fuels whole processing is employed, while for the production of chemicals either method can be used, as discussed below.

FUELS

The use of wood residues for fuels involves either direct combustion or conversion to another form, which is then burned (Tillman 1978), (see figure 1).

Direct Combustion

In direct combustion, the heat applied to the wood causes either direct combination with oxygen in the solid phase to give glowing combustion, or thermal breakdown of the wood components (pyrolysis) to give gases, which burn in the presence of oxygen to produce flaming combustion. This has been used as the method for releasing the energy of wood since man discovered fire, and although we have made tremendous scientific and technological advancements in recent years, this is still the principal means for using wood as a fuel.

I. Direct Combustion

II. Conversion Processes

A. Thermal

1. Pyrolysis (destructive distillation)

2. Gasification

3. Liquifaction

B. Nonthermal

Hydrolysis and fermentation

Figure 1.--Methods of obtaining fuels from wood.

All forest residues, foliage, bark, and wood can be processed by combustion, but give different quantities of energy on a weight basis. The heat content for the foliage, twigs, and bark of nine western conifers was recently measured. In most instances these tissues had a slightly higher heat content than the corresponding wood, (see table 2) (Kelsey and others 1979, Shafizadeh and DeGroot 1976). Also, the heat content of sound dead wood is the same as the original green wood (see table 1) (Lieu and others 1979).

Conversion Processes

In fuel conversion processes, wood components are changed into a different form, either gas, liquid, or solid, and then burned. These processes can be divided into two general categories, thermal and nonthermal.

Thermal methods include pyrolysis, gasification, and liquifaction (Tillman 1978). Pyrolysis, also known as destructive distillation, is merely the heating of substances in the absence of oxygen. The products from wood pyrolysis are gaseous volatiles and charcoal, both being useful as fuel. It is possible to fractionate the volatiles and isolate methanol and other useful chemicals (see table 3). This is the oldest method of conversion known, having been used to produce charcoal for metal smelters as early as 3500 B.C.

Gasification and liquifaction are extensions and modifications of the pyrolysis process. In gasification, like pyrolysis, the initial products are gaseous volatiles and charcoal, but the process is often carried out in the presence of a limited amount of oxygen. The volatile tars and oils are removed to leave producer gas, a fuel composed of differing levels of CO_2, CO, H_2, CH_4, N_2, and H_2O. The tars, oils and charcoal can be recycled to enhance the conversion to producer gas.

Liquifaction can provide two types of fuels, methanol or heavy oil. To obtain methanol, the CO and H_2 from the gasification producer gas described above, are combined using heat and a catalyst. For heavy oils, producer gas, steam, hydrogen, and finely ground wood are heated to high temperatures under pressure in the presence of a catalyst. The heavy oils are somewhat like heating oil.

Table 2.--Heat of combustion for various fuels.

	BTU/lb
Softwood Forest Residues	
Wood	8,000 - 10,000
Bark*	8,500 - 11,000
Twigs*	8,500 - 10,000
Foliage*	8,500 - 9,500
Other Fuels	
Coal	6,500 - 14,000
Methanol	9,000 - 10,500
Ethanol	12,000 - 13,000
Gasoline	21,000

*Determined for nine conifers in the Northern Rocky Mountains (Kelsey and others, 1979).

Table 3.--Yield of pyrolysis products from 100 kg of softwood.

Product	Yield (kg)	Product	Yield (kg)
Charcoal	32.0	Turpentine oil	0.6
A-Tar	7.0	Light oil	0.4
B-Tar	3.0	Methanol	1.0
Acetic acid	1.7	Uncondensable gases	22.0
Acetone	0.8		

Ethanol, a liquid fuel, can be obtained from wood residue by nonthermal means, and primarily involves conversion of the cellulosic fraction, which is hydrolyzed to glucose sugar with acids (Rogers 1979) or enzymes (Nystrom and others 1978). With the aid of microorganisms the sugar is fermented to alcohol, which after purification can be burned directly or combined with gasoline for gasohol.

In view of the large energy requirements of the forest products industry, perhaps the best means of utilizing wood residues is through partial gasification, where the gases are burned for industrial energy and the char is sold as a solid fuel.

CHEMICALS

The type and variety of chemicals that can be produced from wood residues is almost unlimited. Edwards (1975) indicated that from a casual survey of 50 chemicals produced in the greatest quantities in the United States in 1973, 35 of them could be made from cellulosic materials. Obviously it is not economical to produce all of the compounds at the present time, because of less expensive alternative sources, but the potential is available. For the production of chemicals, the components in the woody residues can be treated together or separated and then processed into useful substances.

Pyrolysis, as discussed above, can convert wood into fuels, or it can be used to produce various chemicals. The compounds obtained are determined by the pyrolytic conditions. The old destructive distillation processes gave methanol, acetone, acetic acid, turpentine, light oil, and tars in proportions listed in table 3. By carefully controlling conditions it is possible to produce high yields of tar that are rich in anhydrosugars, which can be isolated or hydrolyzed to glucose (Shafizadeh and others 1979), (see table 4).

Table 4.--Pyrolysis of wood-derived materials at 400°C under vacuum. (Shafizadeh and others, 1979).

	Percent yield from substrate				
Substrate	Gas	Char	Tar	anhydro-1/ sugars	D-glucose (after hydrolysis
Cottonwood					
Untreated2/	37	16	47	3 (6)5/	5 (12)
1% H_2SO_4 wash	36	12	52	10 (22)	14 (31)
Cottonwood lignocellulose3/	11	18	71	37 (63)	46 (78)
Cottonwood holocellulose4/	25	9	66	32 (57)	40 (71)

1/Combination of levoglucosan and 1,6-Anhydro-β-D-glucofuranose.
2/Extracted and washed with water.
3/Prepared by prehydrolysis with dilute H_2SO_4, washed with water to neutrality.
4/Washed with 1% NaOH, then 1% H_2SO_4.
5/Percent yield based on cellulose content of substrate.

The H_2, CO, CH_4, and N_2 in producer gas can be recombined by various synthetic methods to yield ethylene, ammonia, or methanol. In turn these can then be further modified into numerous useful chemicals (Edwards 1975).

The other approach is to separate the extractives, cellulose, hemicellulose and lignin, and then convert each into desired products. The separation could be achieved by weak acid prehydrolysis to remove the hemicellulose and some extractives. The lignin and cellulose (called lignocellulose) could be separated by pulping or converting the cellulose to sugars by hydrolysis or pyrolysis.

The extractives in wood are predominately volatile oils, fatty acids, and resin acids (Zinkel 1975, Ward 1975). These materials or products derived from them have found a variety of uses down through the ages, and although they can be obtained by several different methods, today most are produced as a by-product of kraft pulping in the form of sulfate turpentine and crude tall oil. These can be further refined into numerous products. Turpentine (volatile oils) can be converted to pine oils for use in mineral flotation, solvents, and synthetics. Fatty acids are commercially important for intermediate chemicals, protective coatings, and the manufacture of soaps and detergents. Resin acids are valuable for paper sizing, and rosin soaps are used in the manufacturing of synthetic rubber. They also have uses in adhesives, chewing gum, and other similar materials. All of these extractives could be obtained from wood residues, and the markets are already established for the products.

Cellulose is a polymer of glucose sugar units, linked together in a linear chain. The polymeric products include paper, or through regeneration, rayon, cellophane, and other derivatives. Cellulose can be hydrolyzed to glucose sugar by acids or enzymes (Rogers 1979, Nystrom and others 1978), and interesting anhydrosugars can be formed by pyrolysis (Shafizadeh 1975, Shafizadeh and others 1979). These anhydrosugars can be isolated or converted to glucose by a mild hydrolysis step. The glucose can be used as a sweetener or it can be enzymatically converted to a mixture of glucose and fructose in a honey-like syrup. The glucose solutions can also be used as an energy source for the growth of microorganisms, such as yeast. Specific components of the microorganisms could be isolated including protein, nucleic acids, fat, vitamins, and other organic molecules. Fermentation can convert the glucose to ethanol for fuel or a feedstock for other chemicals such as ethylene, a starting material for a variety of chemicals including synthetic fibers and plastics (Edwards 1975).

Hemicelluloses are short polymers of five and six carbon sugars, which unlike cellulose are usually branched (Schuerch 1963). These are easily hydrolyzed, xylose being the most common five carbon sugar, and mannose the most common six carbon sugar obtained in this way. Mannose can be fermented to ethanol or converted to mannitol, a dietetic sweetener (Herrick and others 1975). Xylose can be made into xylitol, also an artificial sweetener, or to furfural (Harris 1977) for use in adhesives, resins, and polymers.

Lignin is a three dimensional polymer composed of phenyl propanoid units which acts as a cementing material in plant cell walls (Sarkanen 1963). Unlike cellulose and hemicelluloses, lignin is chemically heterogeneous, and cannot be readily converted or broken down to a single component, but instead yields a complex mixture of phenolics. The mixed phenolics can be obtained by destructive distillation, hydrolysis, pyrolysis, and hydrogenation (Goldstein 1975). Lignin and its degradation products have been used in forming resins, thermoplastics (Lindberg and others 1975), polyurethane foams (Hsu and Glasser 1975), and speciality chemicals such as vanillin (Goheen 1971).

CONCLUSION

Wood residues are a chemically heterogeneous renewable resource that can be used for the production of fuels and chemicals. Because of their complexity, they have the potential to be converted into a wide variety of products that could replace many of the chemicals currently supplied by the petroleum industry. The realization of a wood chemicals industry is hindered more by the economics of the processes rather than by the technology.

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TECHNICAL AND ECONOMIC ASPECTS OF HARVESTING DEAD LODGEPOLE PINE FOR ENERGY

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ABSTRACT

This study highlights the results of a study of the economic feasibility of harvesting dead lodgepole pine for fuel and products. Costs, production rates, and recoverable wood volumes were obtained from a 3-month study of a whole-tree logging operation in which dead lodgepole pine was harvested for fuel and products.

KEYWORDS: Lodgepole pine, harvesting, energy, residues

National energy problems have drawn attention to wood as a source of energy. At the same time, wood residue in dead timber is creating serious forest land management problems in the West. An obvious and desirable solution is to utilize the dead timber for energy and other products. The solution, however, requires that the dead timber be harvested, transported, and converted to products including fuel, in an economic and environmentally acceptable manner.

The USDA Forest Service, in cooperation with the Department of Energy, is studying the economic feasibility of harvesting dead lodgepole pine timber for energy and other products. Harvesting operations using mechanized equipment for falling, yarding, delimbing, bucking, sorting, chipping, and loading were studied for three months this past summer in the dead lodgepole pine stands of eastern Oregon. Cost, production rate, recoverable wood volume, wood fuel characteristic, and environmental effect data were obtained. This presentation focuses on technical and economic aspects of harvesting dead lodgepole pine for energy. It is based on personal observations and some preliminary analyses of information gathered during the study. Since study analysis and reporting are in progress, the information presented here is preliminary and subject to change.

The logging contractor for the study was Crisstad Enterprises, Inc.,1/ which has considerable experience in harvesting dead lodgepole pine timber from northeastern Oregon. It is a whole-tree chipping operation. The chips are trucked to the U. S. Gypsum plant at Pilot Rock, Oregon, where they are used in manufacturing fiberboard.

The basic harvesting equipment used by Crisstad includes John Deere 544B/Rome feller bunchers, Caterpillar 518 and Clark 667 skidders with Esco 36 grapples, and Morbark Model 18 and Model 22 chippers. Support equipment includes shuttle trucks for vans, crawler tractors, water pumper trucks, fuel trucks, crew rigs, and mechanic's truck. Chip and log trucking are contracted.

A Hahn tree-length delimber and a log loader were added to the equipment array during the study. This equipment was used in several different configurations or systems to recover logs of sufficient quality, diameter, and length for available markets. The log markets included house logs and dead and green saw logs.

During the study, cutting units on timber sales in the Umatilla and Wallowa-Whitman National Forests were harvested. The units ranged from about 15 to 35 acres in size. All of the lodgepole pine trees on the units were clearcut, green as well as dead. The average diameter at breast height (d.b.h.) of the lodgepole stands ranged from 5 to 9 inches. Most of the lodgepole pine had been dead for 4 or 5 years.

Initially, the Hahn delimber was operated alongside a chipper. The skidder brought turns beside and in between the two machines. The loaders on the machines sorted and fed tree stems as appropriate, and tops from the Hahn were chipped as they developed. Time spent in sorting and waiting for input material slowed production in both machines.

The Hahn delimber was also operated separately from a chipper. To speed production, the feller-buncher operator separated stems by diameter as much as possible for the skidder. Trees that contained no logs and tops from trees that did were decked by the Hahn for later chipping. The Hahn also sorted the manufactured logs according to market specifications. This sorting slowed production.

On some cutting units, no logs were produced due to small stem size. The 3-month period of the study covered a variety of stand conditions as well as harvesting procedures.

The chip material probably has the most potential for being used as an energy source. Lodgepole pine wood has a heating value of about 8600 Btu/lb. (over 3,800 Btu per kg.).

The average weight of the wood in the chip vans was about 42,500 lbs. (19,000 kg.) as loaded, and 32,500 lbs. (14,700 kg.) bone dry. So there were about 13.5 bone dry units (2400 lbs. or 1,080 kg.) per chip van.

About 20 to 55 dry tons/acre of chips and logs were removed. Approximately 7 to 27 dry tons of wood were left on the ground as slash or logging residue. Much of this was already down prior to harvesting and caused problems for the feller/buncher and the skidder operators.

1/ The use of trade, firm, or corporation names does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

Machine production rates were quite variable because of a number of factors. Production ranges were:

	(Dry tons/hour)
Chipper	5 to 20
Feller-Bunchers	8 to 18
Skidder	10 to 13

With no delays and everything working right, the Model 22 chipper could produce about 40 dry tons/hour.

The diesel fuel used in producing chips was monitored. It appears that the diesel fuel requirements per van load of chips (13.5 bone dry units) are:

Chipper	12.5 gallons
Feller-buncher	7.0 gallons
Skidder	8.2 gallons

This presentation has discussed some highlights of the harvesting study underway on dead lodgepole pine in northeastern Oregon. Work on a comprehensive report on the study is in progress. The report should be published by the USDA Forest Service, in 6 to 9 months.

INTERMOUNTAIN REGION WOOD UTILIZATION AND WOOD ENERGY APPLICATION PROGRAM

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ABSTRACT

There continues to be a high level of interest nationally in accelerating the use of wood residue as an energy source. On September 15, 1978, the U.S. Forest Service initiated a National Wood Utilization and Wood Energy Application Program to focus attention on application of existing and developing technology. The mission and goals of this program are discussed.

On March 20, 1979, the Regional Forester, Region 4, approved a Wood Utilization and Wood Energy Application Program for the Intermountain Region. Highlights of the program are reviewed, including mission and goals, planned wood energy symposium, firewood programs 1976-79, conflicts between home and industrial use, forest residue inventory, and priorities of forest residues utilization.

Problems that need to be faced, such as access, economic feasibility, and long-term guarantees are discussed.

The benefits and hazards of utilizing forest residues are summarized and the paper closes with mention of the U.S. Forest Service and Regional commitment and the future opportunities for wood energy.

KEYWORDS: wood energy, wood residues, firewood, wood utilization

INTRODUCTION

Many people have recently come to recognize wood as a potentially important source of energy that can be substituted for scarce fossil fuels. In fact, substitution of wood for fossil fuel is now occurring at an accelerating rate. The emergence

of wood residue as an important forest product in the United States can be very important to the Country. It can be a valuable adjunct to forest management or it can be a major management headache. In any case, the increasing use of wood as fuel is here and not likely to disappear.

There is a high level of interest nationally and in the Intermountain Region in further accelerating the use of wood residues as an energy source. Currently, unused residues represent a significant potential energy resource. The major components of the residue resource are (1) logging slash and cull material, (2) dead timber considered unmerchantable and (3) submerchantable small trees. Opportunities for using this wood to generate energy include direct use as a fuel, modification to create more efficient solid fuels, or conversion to methanol or other liquids or gas forms.

Proposed Legislation

Some of the national interest is evidenced by a number of bills being presented to both the House and Senate--six bills are now before Congress. On September 19, 1979, Senator Talmadge introduced Senate Bill S-1775 on behalf of himself and 28 other senators, including Senators Melcher of Montana and McClure of Idaho. This bill is called the Agricultural, Forestry and Rural Energy Act of 1979.

The purpose of the bill is to:

(1) Establish the USDA as the lead agency for development and production of alternate fuels from biomass.

(2) Assure the development and implementation of energy production and conservation programs in agriculture, forestry, and in rural communities. The explicit goals are to achieve (A) net energy independence for agriculture and forestry and (B) a 50 percent reduction in petroleum and natural gas use by rural communities by the year 2000.

(3) Create an agricultural, forestry and rural energy board within the USDA.

National Wood Utilization and Wood Energy Application Program

On September 15, 1978, the Chief of the Forest Service and his staff agreed to initiate a National Wood Utilization and Wood Energy Application Program to focus attention on the application of existing and developing technology. The mission of the program is to increase the potential for intensive management of forest lands through commercial use of wood products and energy.

The goals under this program are:

(1) To establish markets for residue created by thinnings, timber sales operations, and fire, insect, and disease prevention and suppression activities.

(2) To apply the latest technology to establish and assure the profitability and stability of new residues-related industry.

(3) To provide technical assistance to land managers for use in planning appropriate levels of utilization.

(4) To make optimum use of biomass for energy.

A major aspect of the program is the identification and development of promising energy project demonstrations. One possible activity is the conversion of Federal or other public facilities to wood-based heat and power. The development of wood utilization centers that produce a broad mix of wood products and utilize residues for heat and electricity is another possibility.

All Forest Service Regions and Areas have designated wood utilization and energy coordinators, and have established wood energy committees that include representation from all branches of the agency.

INTERMOUNTAIN REGION WOOD UTILIZATION AND WOOD ENERGY APPLICATION PROGRAM

Over the past several years there have been few areas within the Intermountain Region that have been utilizing wood residues for energy, and this primarily in the form of firewood for home heating and cooking. In 1978, the oil crunch jolted many people to the realization that the days of free and easy energy were limited. In December of 1979, the Regional Forester appointed me as the Regional Wood Energy Coordinator and also appointed a Wood Energy Committee. On March 20, 1979, the committee presented the Regional Forester with the Intermountain Region Wood Utilization and Wood Energy Application Program plan, which he approved.

Intermountain Region Wood Energy Goals

Four goals of our program are (1) through cooperation with the private industry sector, establish markets for wood residue resulting from cultural and fire, insect and disease prevention and suppression activities, (2) to minimize the use of fire in residue disposal activities, enhancing air quality and favoring recovery of residues as an alternative energy source, (3) to assist and encourage potential users and proponents of alternative wood energy products by providing information and technical assistance, assuring that utilization optimizes benefits to the public, and (4) to assure that Forest Service equipment, facilities, and programs are used to demonstrate energy conservation and application of alternative energy source technology.

In order to achieve some of these goals at the earliest possible date, several actions have been taken. We asked four Forests to prepare a preliminary analysis of wood energy projects using a minimum of 2,000 cords of wood per year. We are in the process of analyzing these proposals at the present time. Another of our objectives was to assist the Forests in a review of forest residues and wood energy potentials. A coordination workshop was held in Salt Lake City in May of 1979, with members of all National Forests in attendance. At that workshop we discussed current technologies, resource evaluations, preliminary feasibility analyses, and project preparation. In addition, the attendees were divided into work groups and asked to identify major barriers to the use of residues, and develop strategies for resolution. Of the long list of barriers, problems with budgets, time and personal attitudes were the most frequently cited barriers. The attitude barrier reflects the old way of doing business, such as burning the residue rather than utilizing it.

We are presently planning an energy conference in Salt Lake City for spring. The conference will be mainly on land management problems associated with the use of forest residues for wood energy.

PROBLEMS IN UTILIZING RESIDUES FOR WOOD ENERGY

The Intermountain Region Wood Utilization and Wood Energy Application Program faces many fundamental problems. One of the major problems in promoting increased residues utilization in the industrial sector is the lack of a reliable forest residues inventory. There are inventory models in other regions that predict the amounts of residue resulting from timber sales which we feel might be adapted to Region 4. We are also looking at the possibility of making predictions from the stand inventories conducted as a part of on-going forest management activities. However, to date we do not have a good idea of the amount of residues in the form of dead timber, logging slash and insect and fire-killed material that is available or will be available for energy use. In this Region particularly, the distance between the forest residues and potential markets can also be economically prohibitive.

There is a lack of long-term guarantees of continuous supply. These factors coupled with the question of economic feasibility of wood energy leads to another concern: where is the capital investment for experimental energy projects going to come from?

Currently, the biggest use of forest residues in the Intermountain Region is for firewood. In 1976 the Intermountain Region issued 39,572 permits for free firewood. The total volume cut was 95.9 million board feet or 191,000 cords. In 1977 the number of permits jumped to 50,836 and the volume to 156.6 million board feet of firewood. In 1978, the number of permits increased to 69,400 for a total of 179.4 million board feet or 359,000 cords. In 1979 there were 101,791 permits with a total permitted volume of 251.5 million board feet of timber cut. Overall, there was a 262 percent increase in the number of permits in three years. This points to several very pressing questions. Could a moderate charge for firewood-cutting permits be instituted? If so, can a sound residues management program be developed to deal with the size of the firewood program? I think the answer is "yes" in both cases. Also, the question of increased public access to existing residues, especially where temporary roads are involved, must be considered. Determining the priorities for increased wood utilization between potentially competing public and industrial users is a related problem.

In spite of these problems, there are several proposed energy projects being evaluated at this time in the Region that will utilize mill and/or forest residues. There is a potato-processing plant at Rexford, Idaho that has received funding for a feasibility study of conversion of their Wisconsin and Idaho plants to wood heat. In southern Utah, a forest products firm is studying the feasibility of a pyrolysis process for making charcoal and oils from mill residues. One of the major timber companies in southwestern Idaho has installed a fluidized bed wood-fired bark boiler system for heating their dryers. There are two power companies within the Region that have done feasibility studies on the use of wood for co-generation of electrical power. There is also a proposed gasahol operation in southwestern Idaho. In addition, there are a growing number of commercial woodcutters to meet the heavy consumer demand for wood stove fuel.

BENEFITS AND HAZARDS OF UTILIZING FOREST RESIDUES

Some of the benefits and hazards of increased utilization of forest residues are already apparent. Residue utilization can help accomplish site preparation for regeneration; reduce dangerous fuels accumulation and fire hazards; and provide, through thinnings, a silvicultural benefit. Outside of the forest, residue utilization can improve the local economy by creating employment opportunities in new industries. Most importantly to our program, it can reduce our reliance on fossil fuels.

However, intensive utilization could affect future soil fertility by interrupting the recycling of nutrients; create extreme surface temperatures that might inhibit regeneration; and pose coordination problems involving wildlife habitat.

Commitment to Wood Energy Programs

In closing, let me say that the Intermountain Region is committed to an energy program using wood residues, and while we are a long way from having all the answers, we are putting forth our energies to make this program work for the benefit of all. It is my personal belief that there are many opportunities to use wood residues to help in the fuel crunch. I also think there are many opportunities, small and large, for both individuals and companies to use some imaginative thinking that will pay off in both social and economic benefits.

REVIEW OF BIOMASS GASIFICATION

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ABSTRACT

This paper reviews the topic of biomass air gasifiers. The gasification process chemistry is outlined and the operating characteristics of two types of gasifiers are presented. A few typical applications are discussed and the economics for a particular system are presented in comparison with the costs of natural gas. Finally, the appendix gives a list of biomass research, demonstration projects and manufacturers.

KEYWORDS: gasification, biomass fuel

Biomass air gasifiers offer one of the many contributing solutions to our current energy problems. Interest in these devices increases when more convenient energy sources, such as oil and gas, become scarce or very expensive. Air gasifiers must still compete, however, with other energy uses for biomass, such as heat and steam from direct combustion, pyrolysis processes and even methanol production. Moreover, biomass feedstock end uses must compete in the economic market with requirements for lumber and fiber.

GASIFICATION PROCESSES

The gasification process is simply one of converting a solid fuel into a gaseous fuel. However, there is often some confusion between the terms pyrolysis, gasification and combustion. The distinguishing quantitative characteristic between these conversion processes is the amount of air (oxygen) used relative to the quantity of fuel. One study (Reed and Jantzen 1979) determined that pyrolysis predominates when the air used to convert a given quantity of fuel is less than 20 percent of the theoretical air required for total combustion. The main product from a pyrolysis process is char along with some gases and oils. The gasification process predominates when 25-50 percent of the theoretical air required is used, resulting in a low to medium Btu gas. Finally, the combustion process predominates when the air supply is equal to or greater than 100 percent of the theoretical air required for total combustion. This process results in total conversion of the fuel's chemical energy to thermal energy.

The conversion of solid biomass material to a gaseous fuel involves many separate chemical reactions. The more important of these reactions are given in table 1 along with the heat from the reaction. Besides actual chemical transformation, the physical process of drying wet biomass also is included. All of the reactions, of course, do not yield a gaseous fuel and the main example is reaction 1 (table 1).

TABLE 1.--Thermo-chemistry of gasification.

No.	Reaction	ΔH, BTU/lb-mole	ΔH, kJ/gm-mole	
1	$C + O_2 \quad CO_2$	-169,288	-392.7	Exothermic
2	$C + \frac{1}{2}O_2 \quad CO$	-47,556	-110.6	Exothermic
3	$C + CO_2 \quad 2CO$	+74,160	+172.3	Endothermic
4	$C + H_2O \quad H_2 + CO$	+56,437	+131.2	Endothermic
5	$CO + H_2O \quad H_2 + CO_2$	-17,723	-41.2	Exothermic
6	$C + 2H_2 \quad CH_4$	-32,198	-74.8	Exothermic

When air is used to provide the oxygen source, a large quantity of nitrogen remains after combustion and the nitrogen acts as a dilutant to the resulting gaseous fuel. As can be seen in table 1, some of the reactions are endothermic, and thus, require a heat input from some other reaction before they can occur. This heat input generally is supplied from the highly exothermic reaction #1.

Another important thermodynamic variable that effects the product distribution in the gasification process is the chemical equilibrium constants. While actual equilibrium is seldom attained in an operating gasifier, the equilibrium values and their temperature characteristics are very important. Figure 1 illustrates the equilibrium effects for the reduction of carbon dioxide with charcoal at various temperatures and various gas velocities. The factors to note are the rather large changes in CO concentration as the temperature increases at a fixed flow rate and also the effect of the gas flow rates themselves.

The composition of the product fuel gas will depend on such factors as the type of gasifier, the moisture content of the biomass feedstock, the gas flow rate, the operating temperatures, and the oxygen concentration of the air. The total enthalpy of the gas will depend on the above factors as well as the gas temperature, when it is used, and its moisture content.

Most air-blown gasifiers yield a gas composition within the ranges shown in table 2. The updraft gasifiers also contain tars that increase the chemical energy content of the gas if they remain in the gas phase before being burned.

The effect of biomass moisture content on the heating value of the gas is shown in figure 2. This reduction in heating value limits the material with use of biomass in downdraft gasifiers to about 30 percent wet basis. Updraft gasifiers can accept material with a moisture content up to 50 percent before the thermal performance is severely affected.

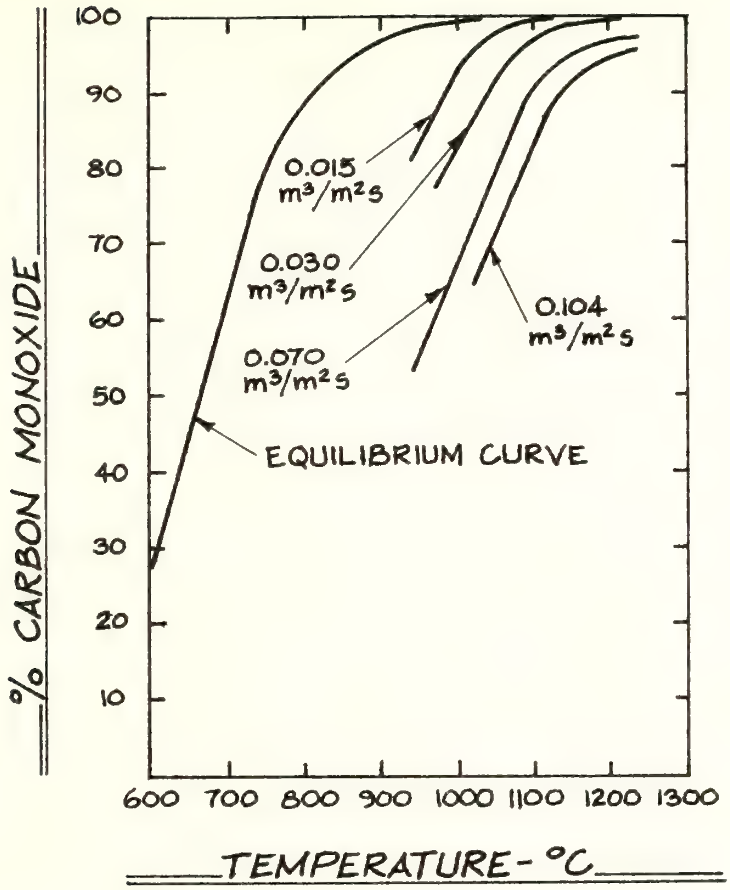

Figure 1.--Carbon monoxide concentration as a function of temperature and flow rates over heated charcoal (Widell 1950).

Table 2.--Typical gas analysis from downdraft gas producer using wood (Allcut and Patten 1943)

Gas		Range % by Volume
CO_2		9.5 - 9.7
O_2	Non-Combustible	0.6 - 1.4
N_2		50.0 - 53.8
Hydrocarbons		0 - 0.3
CO		20.5 - 22.2
H_2		12.3 - 15.0
CH_4		2.4 - 3.4
Heat Content, HHv		138 - 149 BTU/SCF

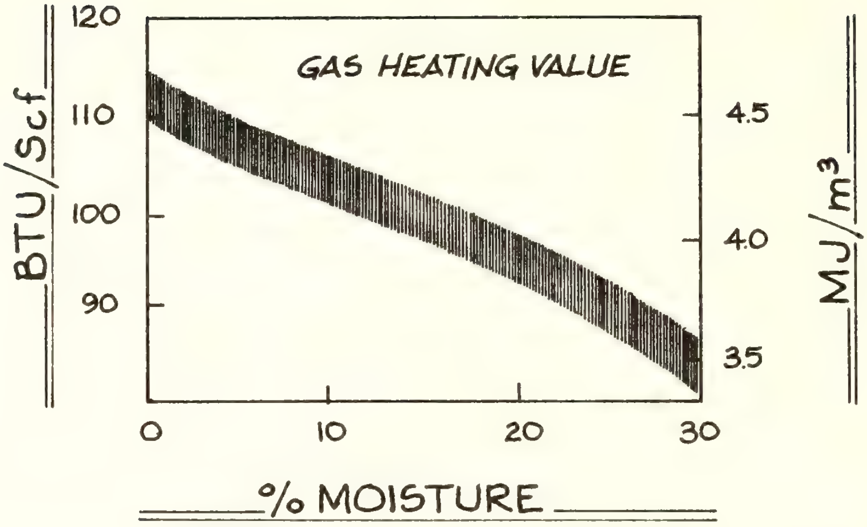

Figure 2.--Effect of moisture content on gas heating value for downdraft gasifiers. (Gumz 1950).

GASIFIER CONFIGURATIONS

Many different configurations have been used for gasifiers and the main differences are where the air is introduced and where the resultant fuel gas is extracted. The classical gasifiers, the updraft and downdraft types, are shown in figures 3 and 4. In the updraft gasifier, the air is introduced into the combustion zone immediately above the ash pit. Oxidation reactions 1 and 2 (table 1) occur, generating CO and CO_2 plus a great deal of heat. These gases pass upward through the biomass and their temperature is continually reduced. Some of the gases further react and generate H_2 and additional CO. Volatile oils are driven from the incoming biomass and these, along with the moisture, leave the gasifier.

The downdraft gasifier differs in that the reduction zone is the last one encountered by the existing gas. This process results in much lower volatile oil and tar content of the gas since these compounds crack into gases as they pass through the hot reduction zone. The reaction zones and predominate reactions that occur there are shown in figure 5 for a downdraft gasifier.

There are many variations on these basic designs. Biomass gasifiers range in size from 10^5 Btu/hr to 10^8 Btu/hr. The system design is highly dependent upon the end use and the desired or required heat content of the gas.

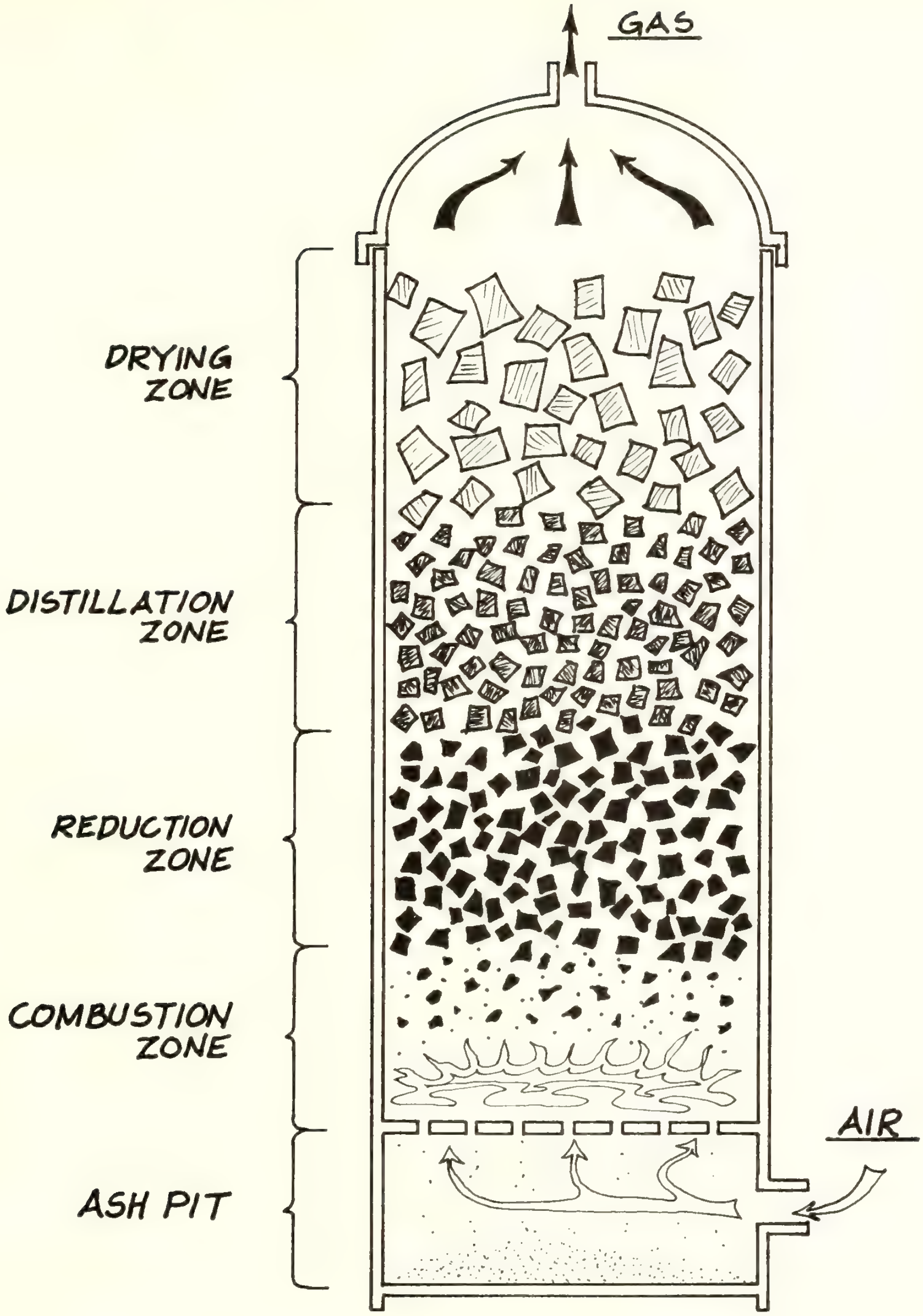

Figure 3.--Updraft gasifier.

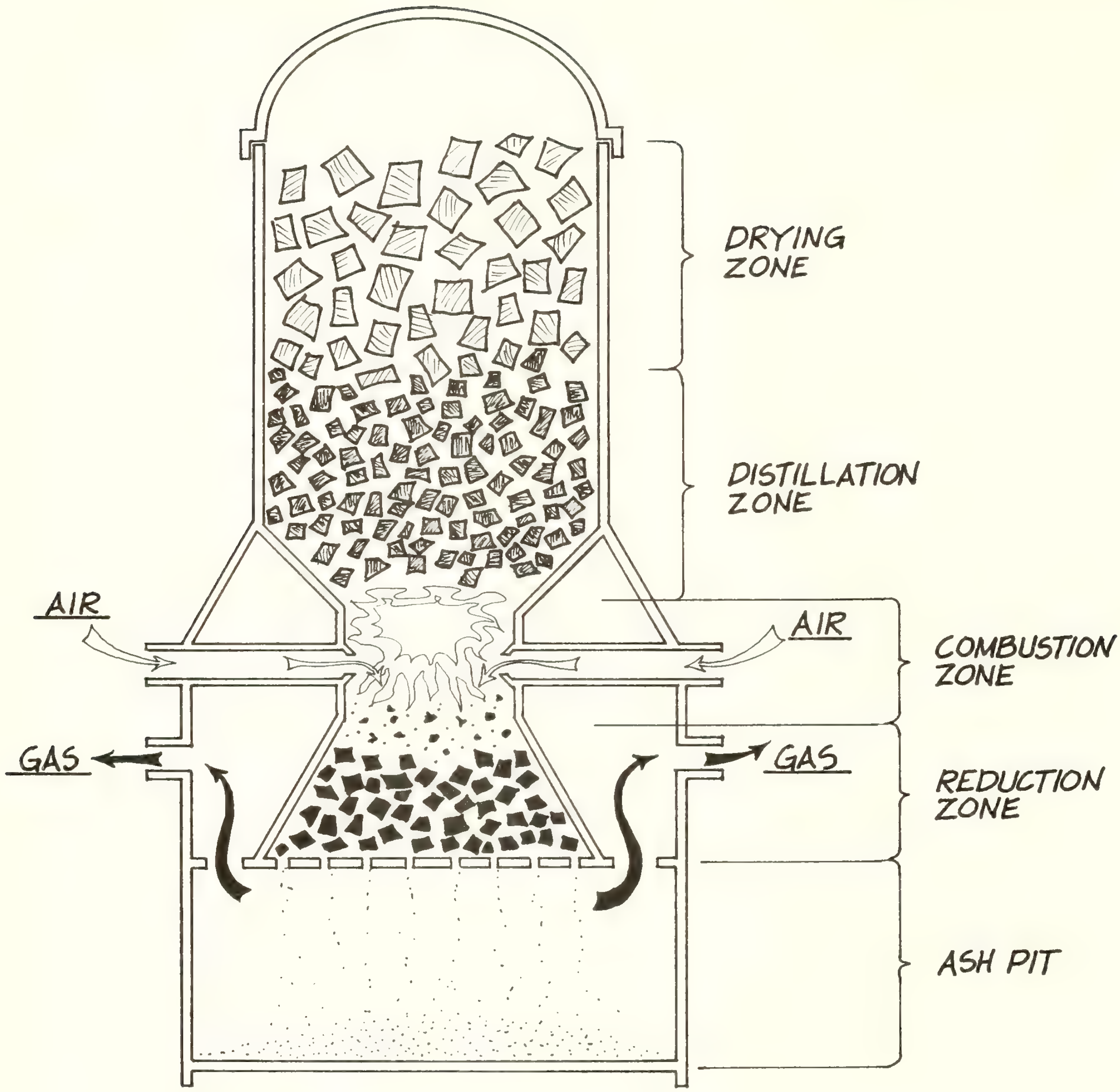

Figure 4.--Downdraft gasifier.

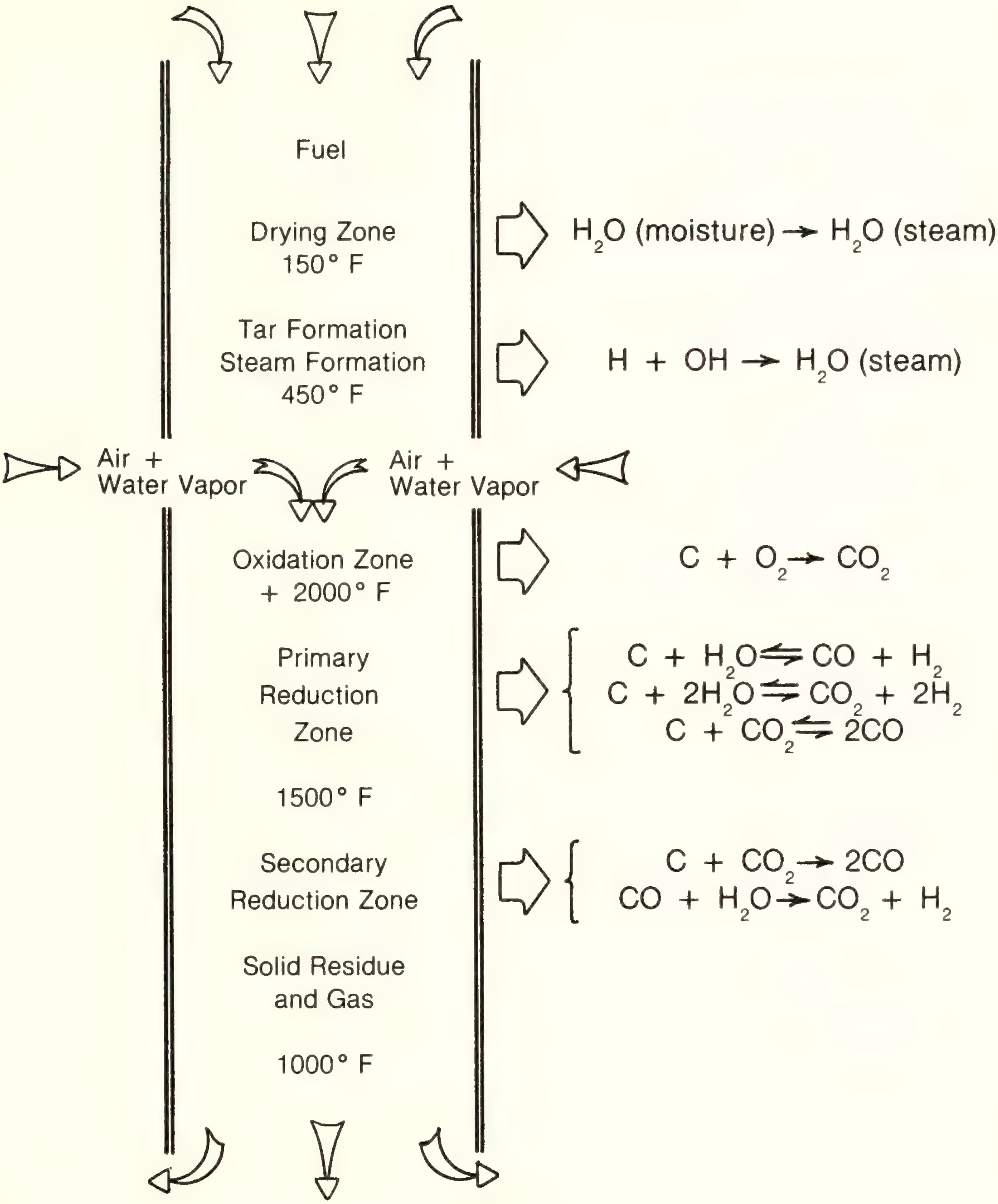

Figure 5.--Reaction zones in a downdraft gasifier.

APPLICATIONS

Gasification of organic materials for power and fuel have been utilized since 1857 when the Siemens brothers in Germany developed a successful gasifier using coke for fuel. By 1923, stationary gasifiers had been designed for and operated with many forms of cellulosic residue. During World War II, up to 700,000 vehicles were equipped with gasifiers to meet the problem of liquid fuel shortages. Today gasifiers are being developed for applications ranging from home heating systems to portable and stationary electrical generators.

One of the most efficient uses of a gasifier is to produce gaseous fuel for an existing gas burner. As shown in figure 6, a boiler's efficiency depends upon the energy content of its fuel. However, for gases with a heating value greater than 200 Btu/scf, the efficiency is essentially constant and equal to that for natural gas. By close coupling the gasifier to the boiler all of the generated fuel gas as well as the sensible heat of the gas stream is utilized. Of course, the size of the fuel line would have to be increased since the fuel gas only has about 150-200 Btu/SCF compared to natural gas with 1000 Btu/SCF.

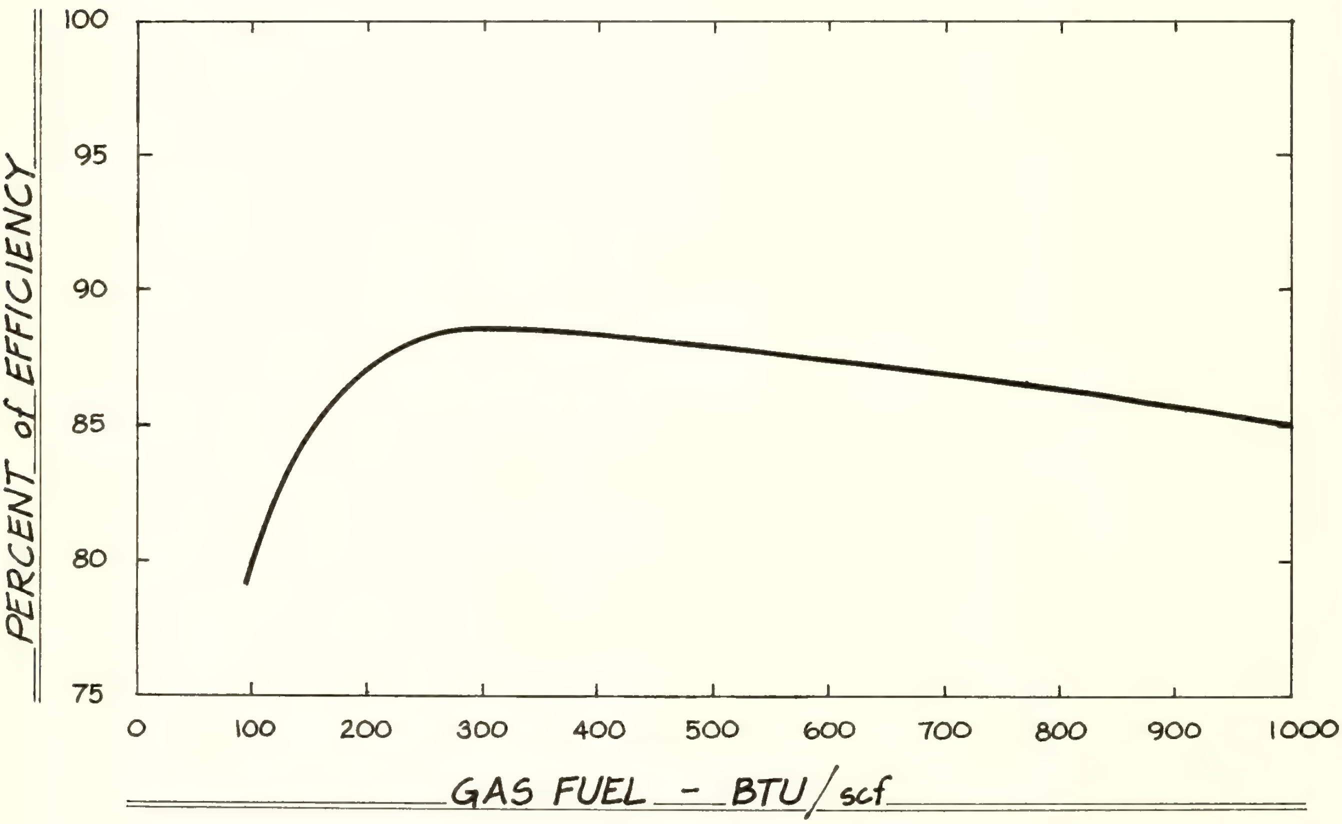

Figure 6.--Gaseous burner efficiencies (Bechtel 1975).

Another application of biomass gasifiers is to produce fuel for an internal combustion engine, either spark or compression ignition types. The Swedish experience with gasifiers providing fuel for vehicles shows both the technical feasibility as well as the many drawbacks. Thus it is not expected that gasifiers will find much general acceptance for mobile applications.

In general, though, there is a great deal of interest in developing and testing biomass gasifiers. Appendix A lists biomass air gasifiers research, development, and demonstration programs around the country. The University of California - Davis gasifier has been demonstrated at the state heating plant in Sacramento as well as at the Diamond/Sunsweet walnut processing plant as a source of fuel for steam generation. Moteurs Durant units have been delivered and installed in Europe, Africa, Asia and Central America to provide electrical power from biomass via an air gasifier.

ECONOMICS

The accurate determination of fuel gas costs from a biomass gasifier is a very complicated exercise. The capital cost for the gasifier is probably the easiest parameter to determine, but the cost of capital, which depends on many arbitrary decisions, is very difficult to determine. For the purposes of this review paper, only the operating cost of gasification will be compared with that of natural gas. In this analysis, assumptions must be made, including an assumed cost of the biomass feedstock (table 3).

Table 3.--Assumptions used to determine operating cost of gasifier.

Peak demand for heat	15×10^6 Btu/hr
Capital Cost of gasifier and installation (ref. 6, 7)	$340,200
Cost of Capital	15%
Operating Costs (ref. 6, 7)	$37,010/yr.
Operating Cost inflation factor	7%
Heat content of feedstock	17×10^6 Btu/ODT
Gasification efficiency	80%
Yearly heat demand	118.8×10^9 Btu
Feedstock inflation factor	10%

The most sensitive economic factor in all end uses of biomass is the cost of biomass feedstock. This is true for gasification processes as well as ethanol production from grain. There have been many studies of the cost of delivered forest residues (Pratt 1978, Johnson 1978, Mattson 1978) and the values range from $15 to $35/ODT.

Figure 7 shows the operating cost of gasification for three selected biomass feedstock costs as a function of year. Compared to each feedstock cost are the future prices of firm industrial natural gas assuming various rates of increase. The 24 percent increase per year reflects the history of natural gas prices over the past nine years (Montana Power 1979). As illustrated, the cost of gas from biomass gasification is less than the industrial rates for natural gas for all years at a feedstock cost of $20/ODT. However, for a feedstock cost of $45/ODT, the crossover points are 5 to 10 years into the future before gasification can compete with natural gas.

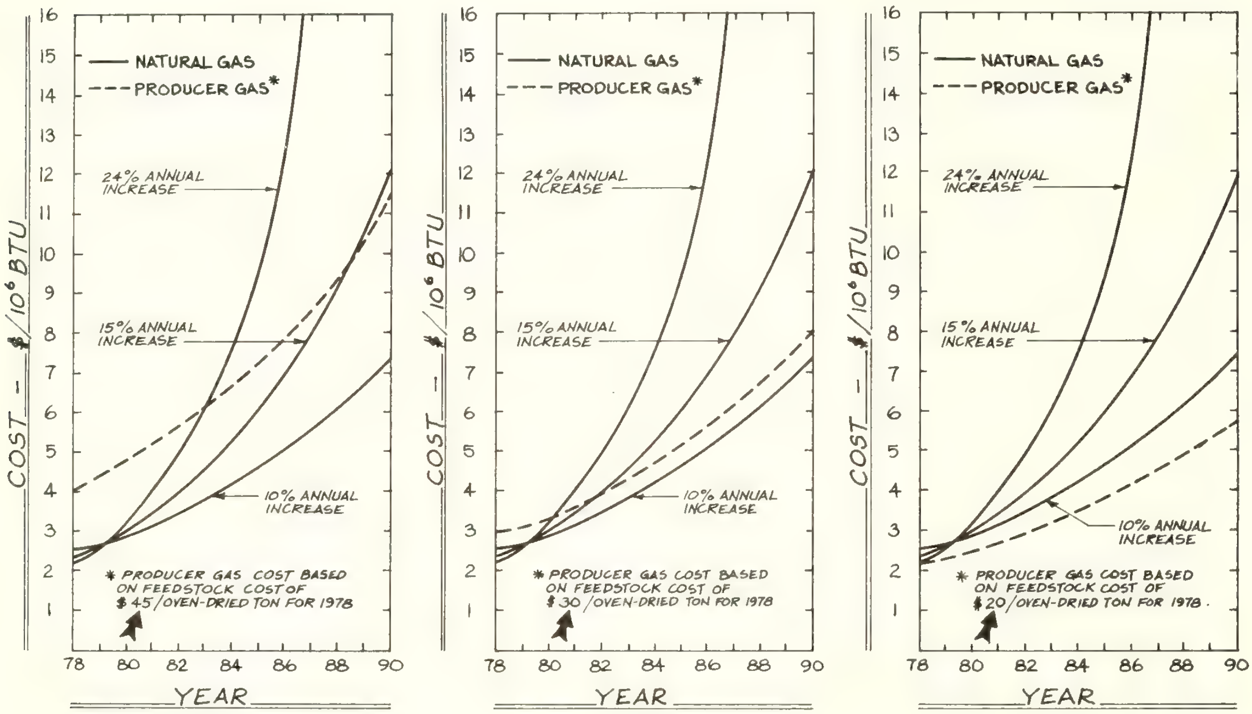

Figure 7.--Cost comparison curves, natural gas and producer gas.

In any event, each potential user of biomass as a fuel must determine his own economic situation and operating costs. There are many factors to consider from both a technical and an economic viewpoint.

CONCLUSION

1. The gasification of forest residues is a proven technology.
2. Commercial biomass gasifiers are available but not yet widely accepted.
3. Low Btu-gas can be used for heating and for power end-uses.
4. The cost of gas from biomass gasifiers is strongly dependent upon the cost of biomass feedstock.

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APPENDIX

Biomass Gasifier Projects

Organization	Status
Alberta Industrial Developments Ltd. 704 Cambridge Building Edmonton, Alberta Canada T5J 1R9 (403) 429-4094	Fluid bed reactor 30×10^6 Btu/hr Prototype ready for commercial use.
Applied Engineering Co. Orangeburg, SC 29115 (803) 534-2424	Updraft, 5×10^6 Btu/hr commercial demonstration.
Bio-Solar Research & Development Corp. 1500 Valley River Drive Eugene, Oregon 97401 (503) 686-0765	Updraft, small pilot scale.
P.C. Walkup Battelle - Northwest P.O. Box 999 Richland, WA 99352 (509) 946-2432	Updraft, commercial and research stage.
B.C. Research 3650 Wesbrook Mall Vancouver, B.C. Canada V6S 2L2 (604) 224-4331	Fluidized bed, 10^6 Btu/hr, research.
Department of Agricultural Engineering University of California Davis, California 95616 (916) 752-1421	Downdraft, 6×10^6 Btu/hr, demonstration.
Century Research, Inc. 16935 S. Vermont Avenue Gardena, California 90247 (213) 327-2405	Updraft, 50×10^6 Btu/hr, commercial.
Davy Powergas, Inc. P.O. Box 36444 Houston, TX 77036 (713) 782-3440	Updraft, commercial.
John Deere & Company Technical Center 3300 River Drive Moline, Illinois 61265 (309) 757-5275	Downdraft, 100 kW generator, research.

Eco-Research, Ltd. P.O. Box 200, Station A Willodale, Ontario Canada M2N 5S8 (416) 226-7351	Fluidized bed, 15 x 10^6 Btu/hr pilot plant.
Environmental Energy Engineering Inc. P.O. Box 4214 Morgantown, West Virginia 26505 (304) 983-2196	Fluidized bed 3 x 10^6 Btu/hr pilot plant.
Forest Fuels, Inc. 7 Main Street Keene, New Hampshire 03431 (603) 357-3319	Updraft, 1-30 x 10^6 Btu/hr pilot-commercial.
Foster Wheeler Energy Corporation 110 S. Orange Avenue Livingston, New Jersey 07039 (201) 533-2667	Updraft, research.
Biomass Corporation 951 Live Oak Boulevard Yuba City, California 95991 (916) 674-7230	Downdraft, 1-15 x 10^6 Btu/hr commercial.
Engineering Experiment Station Georgia Institute of Technology Room 1512 A C&S Bldg. 33 N. Avenue Atlanta, Georgia 30332 (404) 894-3448	Updraft, 0.5 x 10^6 Btu/hr research.
Halcyon Associates, Inc. Maple Street East Andover, New Hampshire 03231 (603) 735-5356	Updraft, 6-50 x 10^6 Btu/hr commercial.
Imbert Air Gasifier 5760 Arnsberg, 2 Steinweg Nr. 11 Germany	Downdraft, 10-10,000 kW generator commercial.
Lamb-Cargate Industries 1135 Queens Avenue New Westminister, B.C. Canada V5L 4Y2 (604) 521-8821	Updraft, 25 x 10^6 Btu/hr commercial.
Moteurs Duvant Industrial Development & Procurement One Old Country Road Carle Place, NY 11514 (516) 248-0880	Downdraft, 1-8 x 10^6 Btu/hr 100-750 kW generator commercial.

Pioneer Hi-Bred International 4700 Merle Hay Road Johnston, IA 50131 (515) 245-3721	Downdraft, 9×10^6 Btu/hr research.
Vermont Wood Energy Corp. P.O. Box 280 Stowe, Vermont 05672 (802) 253-7220	Downdraft, 8×10^4 Btu/hr development.

ECONOMIC AND MANAGEMENT CONSIDERATIONS

Proper management of forest lands involves the integration of many disciplines. When dealing with the utilization of forest residue, principles of economics and business in relation to costs, benefits, and to allocating scarce resources to competing uses are very important. There are, however, numerous other social and biological sciences which the forest manager must use to evaluate harvesting and utilization opportunities for forest residues.

The program participants in this section examine not only economic considerations but also some of the other biologic and social sciences most essential to the proper management of forest lands for multiple and sometimes conflicting purposes as they relate to harvesting the forest residue resource.

VALUE RANKING
FOR UTILIZING LODGEPOLE PINE RESIDUES

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ABSTRACT

Relative values per ton of log input are developed for poles, corral poles, house logs, lumber, studs, veneer, chips, and fuel on a current market basis. The techniques to reevaluate on different markets are demonstrated. Product specifications, demand, and potential to salvage significant volumes are also addressed.

KEYWORDS: Residues, forest products, lodgepole pine, poles, house logs, lumber, veneer, chips

VALUE RANKING FOR UTILIZING RESIDUES

As the title implies, there are many ways of utilizing wood residues. There are also several classes of wood residues. I am going to talk primarily about dead lodgepole pine because there is so much of it available and because there is quite a bit known about the resource.

There are several classes of residues. What was at one time a mill residue problem has become the resource for the paper and particleboard industries. It was almost inevitable that the demand for forest products would force people to look at forest residues as a possible resource base.

There is a huge volume of dead lodgepole pine in the intermountain region and the Rocky Mountains. Virtually all of it could be used for fuel or more valuable products if it were accessible and had a ready market. There are, however, several constraints on use. Each class of possible product has specifications which vary from very stringent (power poles) to almost none (fuel), that affect how much of the product can be used. In addition, some of the products have limited markets or cost more to produce than their current value. This paper will examine the relationship between specifications, value, market and the feasibility of using significant volumes of dead lodgepole pine.

To set the stage for what is too come, I want to start with a 1970 base. At that time, Arabian oil was $1.80 per barrel and other energy sources were priced competitively. Such cheap fuel caused some strange situations. Sawmills were disposing of wood waste in wigwam burners while piping in natural gas to supply energy because the natural gas furnaces were simpler and cheaper than wood burners. The October 1979 issue of Forest Industries has an article on a mill that switched from oil to wood for energy and mentions that the mill switched from wood to oil and gas in 1970.

Federal stumpage then was also relatively cheap. In fact, one of the things that has nearly kept pace with the inflation in energy costs is Federal stumpage rates. (fig. 1)[1]

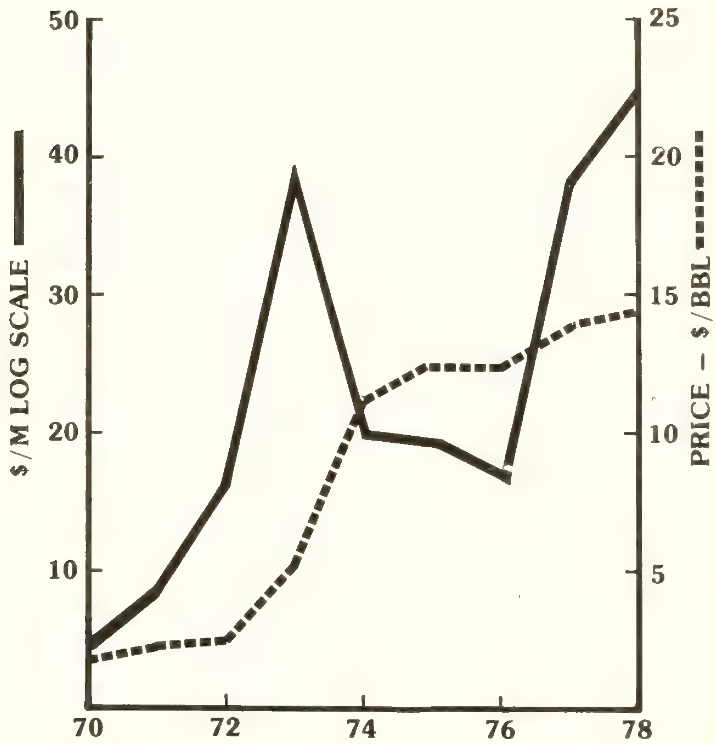

Figure 1.--Stumpage prices, Region 1 lodgepole pine compared to crude oil prices 1970-1978.

The forest products industry has undergone a quiet revolution the past 10 years. Scarcity of wood, which is really only a shortage of preferred species and sizes, plus increased stumpage and energy costs, have changed both the resource base available to mills and to some extent the products produced. Some products such as underlayment particleboard require so much energy (Koch 1976) that production will be converted to more valuable industrial grades or the price will rise to a point where it is no longer competitive.

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[1]Sources: Ruderman 1979 and American Petroleum Institute. 1975 Basic Petroleum Data Book. API, Washington, D.C.

DERIVING VALUE OF FOREST PRODUCTS

To establish a value for a product, a standard unit of measure is needed. The best unit to use would be cubic volume or ovendry (O.D.) weight. Because all composition boards and any processed fuel product involves increased density, I will evaluate everything in dollars per O.D. ton of logs.

Ovendry weight of logs requires cubic feet to derive, but makes it possible to include bark volumes as an integral part of wood volume. It also allows for pricing of all products on the same basis.

The reported wood density of lodgepole pine differs among various sources of information (Foulger and Harris 1973; Maloney 1978). I am going to use 24 lbs per cubic foot ovendry for both wood and bark for either live or dead. The value is in the range for lodgepole pine, and real density varies among different sites as well as among information sources. In addition, dead trees tend to lose bark, not only while standing but during logging and yard handling, so I will use 5 percent of volume for bark on dead lodgepole.

Values used as points of reference are:

B.T.U./lb O.D. wood	9,000	(20 920 kj/kg)
Lb/ft^3 O.D. lodgepole	24	(384 kg/m^3)
Moisture content dead timber (percent)	20	
Bark as percent of stem volume	5	

The main advantage of dead timber over live timber is that the low moisture content is superior for fuel. Low moisture content is advantageous for dry process composition boards and reduces cost of drying lumber or veneer. There is little or no advantage in other products, and there are a great number of disadvantages to logging and processing dead timber (Kohrt 1978; Work 1978).

Potential Products from Dead Timber

There are several products that can potentially be produced from dead timber.

Classes of Forest Products

Round Wood	Solid Wood	Fiber
Poles	Lumber	Particleboards
House Logs	Veneer	Paper
Corral poles		Fuels

Round wood products require sound straight trees over a limited diameter range. Many trees are not large enough or straight and sound enough to produce a product.

Solid wood products have less stringent tree size and quality restrictions than round wood and can, in most stands, remove considerably more volume per acre.

The fuel and fiber products have almost no specifications and could use virtually 100 percent of the volume on an acre.

ROUND WOOD PRODUCTS

Power Poles

Poles are potentially very high value products which can be produced from dead lodgepole pine. Tegethoff et al. (1977) ran a series of plots and destructively sampled to prove that it was possible to produce poles from dead lodgepole. Their

plots averaged 43 trees per acre of power pole size but at least 16 were not suitable because of defect or deformity.

The value of 1 ton of a class 2 treated power pole is very high.[2]

O.D. Wood basis:

	40-foot class 2 pole size			
	Minimum		Median	
Large-end diameter (in)	13.0	(33 cm)	13.5	(34 cm)
Small-end diameter (in)	8.0	(20 cm)	8.3	(21 cm)
Volume (cu. ft.)	26.7	(.75 m^3)	28.8	(.82 m^3)
Weight (O.D. lbs)	642	(291 kg)	692	(314 kg)
Price per pole[3]	$140		$140	
Value/O.D. ton	$436	($480/tonne)	$404	($444/tonne)

I have included an example of the minimum size pole and a pole of median size for a class 2, 40-foot power pole which is near the top end of the size and value for poles. The average sized poles are worth slightly more than $400 per ton ($440 tonne). The volume of bark and trim that develops is not enough to use for fuel on any commercial scale, so there is little or no anticipated by-product value.

Corral Poles

Corral poles are an accepted product from dead lodgepole pine. Value of corral poles including bark:

Length (feet)	16	(4.9 m)
Diameter-average (in)	4.0	(10 cm)
Weight (O.D. lbs)	35	(16 kg)
Price per pole[4]	$2.50	
Value/O.D. ton	$143	($157/tonne)

The value of corral poles is considerably less than the value of power poles; and again, there is no by-product value associated with corral poles.

There are several problems with using timber for poles. Currently few places are accepting power poles from dead timber. They are permitted under pole standards; but buyers usually specify poles from live trees. One problem of dead trees is that blue stain fungus improves permeability (Lower 1978) so treating schedules would have to be changed for dead timber.

Assuming you could get 30 power poles and 300 corral poles per acre, you would be removing less than 15 tons per acre (34 t/ha) of wood. In stands of dead lodgepole pine, volumes approach 100 tons per acre (Dell 1978). Finally, you could meet the demand for small power poles and provide every horse in the West with a private corral and still not touch the acreage that is available.

[2]Cubic volume of wood (Smalian's formula) x 0.95 = volume wood + bark x 24 (lbs/ft^3) = weight.

[3]Price per pole from Cowboy Timber Treating, Inc., November 1979.

[4]Price per pole supplied by Fenus Lumber Co., November 1979.

House Logs

The house log is a relatively popular use for dead timber. The specifications (Peckinpaugh 1978) for logs are quite stringent but vary slightly among manufacturers.

Specifications for House Logs

Minimum diameter		7 inches (18 cm)
Minimum length		16 feet (4.9 m)
Rot allowed		None
Checks	1/4" wide	1 full turn SPIRAL
Crooks		None
Sweep		Minimal
Taper		1 inch in 10 feet (2.54 cm in 3 m)
Bole deformities (cankers, etc.)		Minimal

The minimum diameter, length, and rot restrictions are quite rigid. The other specifications on crook, sweep, and deformities vary slightly with the type of house log being produced (fig. 2). The slabbed four-sided log can accept a small canker or a degree of sweep that would be totally unacceptable for the hand-peeled whole log.

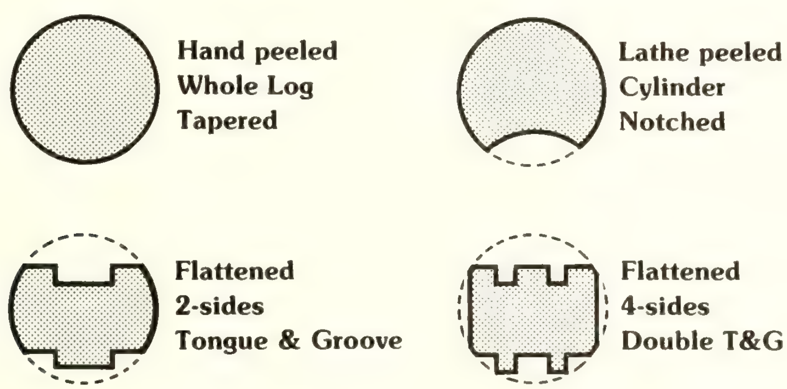

Figure 2.--Some fairly typical profiles of house logs and variations.

The house log price quote used here is for the flattened four-sided tongue and groove log. Round log value varies with log diameter, but no prices were available. Few companies sell house logs; most of them sell only complete house kits.

Value of House Log (Four Sided)

Length-30 feet (9.1 m)

	Minimum		Average		Maximum	
Small-end diameter (in)	7	(18 cm)	8	(20 cm)	11	(28 cm)
Large-end diameter (in)	9	(23 cm)	10.5	(27 cm)	14	(36 cm)
Volume (cubic feet)	11.2	(.32 m^3)	14.9	(.42 m^3)	25.9	(.73 m^3)
Weight-(O.D. lbs)	268	(121.6 kg)	359	(162.8 kg)	653	(296.2 kg)
Value @ $1.20/lin ft[5] ($3.94/lin m)	$ 36		$ 36		$ 36	
Value/O.D. ton	$268	($295/tonne)	$200	($220/tonne)	$110	($121/tonne)

For the minimum size log the values are quite high--$268 per ton. For the average size log the value is down around $200 per ton. The largest logs accepted by house log makers are worth $110 per ton of O.D. wood. In a timber stand of low defect, harvesting house logs could remove 40 to 50 tons per acre at best. Potential by-products from house logs are some chips from squaring log sides and bark and trim for fuel. Most log house operators are too small to install chippers. The predominant by-product sold is the round log trim sold locally as fireplace wood.

The number of log houses built in the United States per year is estimated to be between 20,000 and 50,000. Many of these are smaller second homes in recreation areas. The number of acres that can be used annually by the house log market is large enough to have a significant impact on the problem but falls short of either full utilization or total stand treatment.

SOLID WOOD PRODUCTS

As part of the discussion of solid wood products, it is necessary to establish values of wood as fuel because a real part of the value derived from either peeling or sawing dead timber will be the opportunity to use or to produce fuel as a by-product.

The value of fuel can be estimated from the value of competing fuels although any new energy source would have to be cheaper to offset the cost of new equipment before it would replace the fuel currently being used. In addition, some fuels are cheaper to use because they are cleaner to burn and require little or no storage space.

Natural gas is the perfect fuel. It comes from a pipe with no storage facilities required and is clean burning in simple standardized furnaces.

Oil is only slightly more expensive to use. It varies from slightly dirty to very dirty to burn, and both storage and supply can be problems. Coal and wood burn in similar furnaces.

Coal is dirtier to burn and handle but is more concentrated and easier to store than wood. The following tabulation shows the curent value of wood as a fuel on a heat content basis, using 18,000,000 B.T.U. per ton of O.D. wood.

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[5]Price supplied by Cody Lumber, Inc. for flattened four-sided double tongue and groove log, November 1979.

Cost/Million B.T.U. Basis for Wood Fuel Value

			Values per ton O.D. Wood
Natural gas	@ $.38/therm	$3.80	$68.40 ($75.24/tonne)
Oil #6	@ $.55/gal	3.67	66.00 (72.60/tonne)
9,000 BTU Coal	@ $30/ton	1.67	30.00 (33.00/tonne)
12,500 BTU Coal	@ $40/ton	1.60	28.80 (31.68/tonne)

This establishes a value of wood at fuel as $29 to $30/O.D. ton when compared to coal. It is worth considerably more if substituted for oil or natural gas.

Lumber

Research by the Timber Quality Project at the Pacific Northwest Forest and Range Experiment Station has resulted in a series of dead timber recovery studies throughout the West. In every study, we determined that it is possible[6] (Woodfin 1979) to make lumber from dead trees. The margin available for stumpage is always less than live trees because the volume recovered as lumber is always lower, and the lumber grade or average lumber value is always lower.

The results of most of these studies are just being prepared for publication. We have learned that dead timber suffers severe losses in value when made into 1-inch boards. This results from lumber grading rules which severely limit the amount of blue stain in grade 2 Common and Better.

The value loss at a random dimension mill is much less than at a board mill. Blue stain is not a grading factor for dimension lumber.

At a stud mill, the value lost is even less. Because the price of studs is currently much lower than the price of dimension lumber, a dimension mill is the optimum place to process dead timber right now. If the stud price recovers relative to dimension prices, there would be little difference; but both would have an advantage over a board mill.

What does a sawmill produce from a ton of dead logs? If 30 percent of log volume is recovered as surfaced dry (S.D.) lumber and density is adjusted for shrinkage, the approximate weight of various products results in the following values:

Value Recovered From a Ton of Logs at a Stud Mill

Average lumber value $160/MBF = $236/ton[7]

Lumber	625 lbs (284 kg)	@ $236/ton ($260/tonne)	$73.70
Chips	925 lbs (429 kg)	@ 40/ton (45/tonne)	18.90
Fuel	430 lbs (195 kg)	@ 30/ton (33/tonne)	6.50
Value/ton of logs			$99.70 ($109.67/tonne)

[6]Snellgrove, T. A. 1979. Product value from dead lodgpole pine at three mill types. Unpublished talk, FPRS Annu. Mtg., San Francisco, CA.

[7]Lumber continues to shrink while drying so density of S.D. lumber is 24.8 lbs/ft^3. There are 18.3 bd ft in a cubic foot of S.D. stud volume so 1 MBF lumber = 1,355 lbs. One ton O.D. of studs = 1,476 bd ft of lumber tally.

This value is low because the price of studs is at an all-time low in relation to random length dimension. Recovering the same weight at a random length dimension mill yields a much higher value.

Value Recovered From a Ton of Logs at a Random Length Dimension Mill
Average Lumber Value \$198/MBF-\$286/Ton[8]

Lumber	625 lbs (284 kg)	@ \$286/ton (\$315 tonne)	\$ 89.40	
Chips	945 lbs (429 kg)	@ 40/ton (45/tonne)	18.90	
Fuel	430 lbs (195 kg)	@ 30/ton (33/tonne)	6.50	
Value/ton of logs			\$114.80	(\$126.54/tonne)

It should be stressed that neither of the mills used in this analysis were near the peak of what is technically possible. The stud mill was an old four-saw Scragg and has since been replaced by a modern mill at the same site. The random length dimension mill was a chipping headrig type and was one of the first of that type ever built. Most mills currently in operation could recover more lumber than either of these mills from the same log.

Veneers

Veneer sounds like an implausible use for dead lodgepole pine. The Timber Quality Research group recently ran a veneer study using dead lodgepole pine as the resource. The lathe was a small diameter, high speed, 4-foot lathe. Recovery was much better than we anticipated. The veneer did not fall apart at the checks even during lay-up. It dried on a shorter schedule than the veneer from the live control and laid up into panels so well that the lay-up crew did not recognize that the veneer came from dead timber.

If 40 percent of log volume was recovered as dry veneer, the value would be slightly more than dimension lumber. Veneer does represent a possible use for logs larger than 8 inches in diameter. The following calculations show the value of veneer:

Value From a Ton of Logs in a Veneer Operation

3/16" CD core pine at \$261/ton

Log value/ton	800 lb (363 kg) veneer	@ \$260/ton (\$287/tonne)	\$104.40	
	800 lb (363 kg) chips	@ 40/ton (45/tonne)	16.00	
	400 lb (181 kg) fuel	@ 30/ton (33/tonne)	6.00	
	Value/ton of logs		\$126.40	(\$142.29/tonne)

The major advantages to peeling dead lodgepole are the high recovery potential from peeling small logs on a core lathe and fuel from bark because the residues from the relatively dry logs could be worth more as fuel than as chips to a plywood plant using natural gas for driers.

To wrap up on solid wood products, there are several points to keep in mind. The specifications vary by mill type and product. Veneer plants and board mills tend to require larger diameters than dimension and stud mills. Lumber or veneer manufacture produces large amounts of fuel and fiber products.

Although up to 70 percent of the wood volume is primarily fiber, more than 70 percent of the value is derived from the lumber or veneer.

[8]Actual lumber volume at the dimension mill was 17.9 bd ft/ft^3 of surfaced lumber so 1 MBF of lumber = 1,385 lbs. One ton O.D. dimension lumber = 1,444 board feet of lumber tally.

Solid wood products could utilize from 70 to 85 percent of the total logs available. The fine fuels that are left should be fairly well flattened and susceptible to rapid biological degradation. Also, there are enough potential users to have a significant impact on the acreage of dead timber that is available.

FUEL AND FIBER PRODUCTS

Several fiber products can be produced from dead timber. These products come in many grades and values, but the raw materials used are either chips or particleboard furnish. Because values are low, logging costs become critical and will be considered in fiber products.

Paper

Paper is a relatively high value high cost product. Yields range from about 40 to 95 percent of the wood volume brought into the plant. Prices range from about $375 to $1,000/ton ($413 to $1,102/tonne). The raw material from most paper is chips, a commodity that has established markets and prices.

Chip value	$40.00/ton	($44.10/tonne)
Harvesting	31.40/ton	(34.67/tonne)
Margin for chipping, transport, profit	$ 8.60/ton	($ 9.49/tonne)

A value of $40/ton for chips leaves very little margin for stumpage, logging, and transportation costs. Logging costs range from approximately $20 to $40/ton (Howard 1979) with a fairly realistic estimate for logs to the railhead of approximately $31.40/ton (Grantham 1978). Truck haul costs are approximately $.10/ton mile so a relatively small increase in chip prices can have a large impact on the area which can effectively be logged for chips.

The Champion International mill has a relatively long-standing salvage log chip program (McMichael 1978), which they refer to as the 5-D program, used when sawmills cannot meet their needs from mill residue chips. Use of larger quantities of wood residue by paper mills could be as fuel to meet energy needs.

Particleboards

Particleboards offer a relatively limited opportunity for using any significant volume of dead timber. Underlayment grade particleboard is presently worth $115/ton ($127/tonne) of wood furnish used. Currently, particleboard plants are paying between $5 and $10/ton ($5.50 to $11/tonne) for furnish.

Particleboard furnish	$10.00/ton	($11.00/tonne)
Logging costs	31.40/ton	(34.67/tonne)
Margin	-$21.40/ton	(-$23.44/tonne)

With logging costs at present levels, particleboard is not a viable outlet for forest residues. Its position in the mill residue market is threatened (Fahey and Starostovic 1979) by the value of wood as a fuel.

The development of a structural particleboard industry would allow the use of large volumes of dead lodgepole. A structural particleboard that was directly competitive with plywood CD Exterior sheathing at .6 density and could use 90 percent of log volume would have an upper limit on value of $240/O.D. ton ($265/tonne). The cost to produce this board would be relatively high. Dead timber would be particularly appropriate because particleboard furnish has to be dried to very low moisture content to glue properly.

Fuels

Using no other consideration than B.T.U. values, the maximum value for wood fuel is about $30/ton. There are other considerations, however. Wood burns cleanly, particularly when compared to some coals and oils, and requires no complex air pollution control mechanisms for sulfur compounds.

At large industrial installations, there is no value to processing fuel beyond chipping or hogging the wood to a uniform size.

Fuel Values/Ton

Type	Hog	Briquetted	Pelletized
Value	$30.00	$40-55	$40-55
Logging cost	31.40	31.40	31.40
Preparation	4.00	12.00	12.00
Margin	-$ 5.40	-$ 3.40 to $11.60	-$ 3.40 to $11.60

The potential market for processed wood fuels is limited to small industrial users and institutions (schools, hospitals) which require large amounts of energy but are subject to meeting clean air standards. Processing increases the B.T.U.'s/units of volume. This is a definite advantage in shipping and storing fuels.

SUMMARY

The ability to make commercial products from forest residues depends on the market for products and the ability of the product to compete with existing sources of the same product. The potential to remove significant volumes depends on how well the resource meets specifications of products and the volume of products that the market will accept.

Potential for Using Woods Residues

Product	Value/ton	Demand	Effect on fuel loading
Power poles	$300-400	Small	Little
House logs	110-260	Moderate	Moderate
Corral poles	120-150	Small	Little
Dimension Lumber	90-130	Large	High
Studs	70-100	Large	High
Veneer	90-130	Small	Moderate
Paper (chips)	35-50	Moderate	Very high
Particleboard (furnish)	5-15	None	None
Fuel	15-40	Small	Very high

There are problems with any of these approaches. The most profitable outlets for dead timber have very limited or, at best, moderate demand and leave large quantities of wood residue on the ground. The best solutions in terms of land management have relatively limited demand and, therefore, little potential for treating very many acres. Lumber and veneer have some potential for removing relatively large volumes from a whole lot of acres, but mills are really more profitable operating on green timber sales.

The solution, if one is arrived at, will require cooperation and some creative timber appraisal and sales contract approaches. Sorting, log concentration yards, and land management contracts are the most common suggestions and probably the most appropriate.

Complete tree logging, with separation of the more valuable logs for roundwood and solidwood products, would allow an in-the-woods chipper to operate on concentrations of wood that would not otherwise be commercially possible.

Development of a structural particleboard and fuel market shows the greatest potential for increased demand for forest residues.

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ALLOCATION OF RAW MATERIALS TO ALTERNATIVE PRODUCTS

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ABSTRACT

In traditional timber harvesting operations, the allocation of raw material to alternative products is most often made at the mill. However, in western Montana, because there are no processing facilities equipped to utilize the full range of residue material, the landowner or land manager must make the allocation decision. The allocation process should also be an integral part of sale preparation and not occur as an afterthought at the conclusion of harvest. This paper discusses the utilization of ponderosa pine residue created by a locally severe outbreak of mountain pine beetle in the Blackfoot River drainage northeast of Missoula, Montana.

KEYWORDS: residue utilization, residue harvesting

The allocation of residue to alternative products is a topic which implies a range of markets for the various classes of material. Rather than treat this subject in a general or theoretical manner, I will relate the personal experiences I have had with logging and utilization of residue from second-growth ponderosa pine stands infested by the Mountain Pine Beetle (*Dendroctonus ponderosae Hopkins*.) Although I may repeat some of the material presented yesterday, I will stress the problems and opportunities of allocation as they presently exist in our area.

As manager of the 28,000-acre Lubrecht Experimental Forest, a facility operated by the School of Forestry, University of Montana, my experience is centered in the Blackfoot River drainage northeast of Missoula. The Blackfoot Valley has a history of extensive early logging. As a result, the valley foothills are covered with stands of second-growth ponderosa pine ranging in age from 49 to 90 years, and in diameter breast height (d.b.h.) from 10 to 16 inches--perfect habitat for the mountain pine beetle. The infestation became serious in 1975, and has increased rapidly, reaching epidemic proportions in some locations. Although the outbreaks are not as severe as those in lodgepole pine in other areas of Montana, they are of serious local concern.

For the past five years, the Lubrecht Forest has worked closely with neighboring landowners, public agencies and private industry to effectively salvage and utilize trees killed by the pine beetle. Mr. Bill Potter of the nearby E-L Ranch has been a pioneer in this effort. Not only has he developed and refined a logging system uniquely suited to utilize the various types of residue but he also has willingly provided timber, machinery and personnel for cooperative experiments. At present, to successfully market a variety of residue, the landowner must make a commitment to utilization, must employ an effective logging system and must allocate the material to a variety of outlets.

COMMITMENT TO UTILIZATION

The basis of an effective residue utilization program is a commitment by the landowner to recover the material. Notice that the decision is by the landowner, because residue allocation differs significantly from normal timber harvesting operations where the allocation of raw material (logs) to alternative products is most often made at the mill. The processing facility matches the species, size and condition of the log to the most profitable recovery at current market conditions. The landowner or logger is only peripherally involved by cutting logs to specifications determined by the mill. The manufacturer also makes the decision regarding residue created by the milling process.

However, in dealing with forest residue, the landowner in western Montana must make the allocation decisions because there are currently no facilities which are equipped to utilize a full range of forest residue. In addition, because existing outlets for residue are limited, allocation can be a time-consuming and often frustrating experience. It may even be necessary for the landowner to give raw material to a processor, who can then through trial and error determine its potential marketability. If central residue collection yards were available, the landowner could spend less time on allocation and concentrate on the silvicultural and logging aspects of the program. Once a landowner is committed to using residue, this decision must be implemented early in sale preparation and not at the conclusion of logging. Because of the marginal profitability of the operation, it is necessary to use a closely coordinated logging system which will minimize handling of the raw material.

LOGGING SYSTEMS

There are two basic approaches to harvesting or gathering forest residue. Most classes of material can be removed in an operation either completely separated from or in conjunction with commercial logging. Within the second method, which previous studies have demonstrated to be the least costly, there are also variations.1/ In another paper in these proceedings, Mr. Barger described an approach that used conventional logging machinery to gather residue immediately following the removal of commercial timber. In our operations we remove as much residue as possible prior to commercial harvest. Whichever approach is taken, I believe that it is essential to use a well-planned and systematic logging method to minimize handling and sorting of the residue.

1/ Johnson, Leonard R. Potential for Forest Residue Recovery. Thirty-Fourth Annual Northwest Wood Products Clinic Proceedings. 1979. Engineering Extension Service, Washington State University. Pullman, Washington.

As an example, I will describe the full-tree method developed by Potter which uses machinery consistent with the size and value of the product removed. Although this system is designed specifically for commercial harvesting and salvage operations in second-growth stands of ponderosa pine on gentle terrain, it is applicable to stands of any species under comparable conditions.

In the preparatory step, trees smaller than five inches d.b.h. are hand-felled and piled into bunches for removal to a central landing by a grapple-equipped tractor. Of course the specific trees cut will depend on silvicultural objectives. In our application all dead, infested, leaning and down trees are bunched by a crew consisting of one sawyer and from two to four stackers. Skid trails are cleared in a veined pattern into the stand and the bunches are pointed, butts first, to these prepared trails. Stumps are cut flush to the ground and the size of the bunches depends on the timber and type of skidding machine used. Although production is proportional to the size and density of the timber, the crews average approximately 45 stems per hour per individual.

We have used a variety of machines to move the bunches to a central landing. The first is a Melroe Babcat, Model 722, steer-skid loader, equipped with a homemade grapple.2/ Although this machine is very maneuverable, its relatively low ground clearance and slow travel speed limit its effectiveness to a prebunching role or to very short skids. The second skidder is a small 30-horsepower farm tractor equipped with the same grapple attached to the three-point hitch. This machine has a lower initial cost, higher ground clearance and greater travel speed. In addition, most woodlot owners already have a tractor of this type which could easily be adapted for woods use. Potter uses a grapple-equipped 75-horsepower tractor and its increased size, stability and power enable him to clear two acres per day. For longer skids with large bunches, he uses a standard rubber-tired skidder with a fixed grapple.

The first step prepares the stand for easy entry and enables more efficient operation in the second phase in which dead and designated trees from approximately 5 to 14 inches d.b.h. are harvested with a Model 1075 Melroe Bobcat Feller-Buncher If stand conditions allow, the trees are sorted by size into commercial sawlogs and pole-sized material. In other instances, they are piled together. Production with the Feller-Buncher in a thinning operation ranges from 40-80 stems per hour.

The bunches are then skidded to a landing for processing. Potter has also found that the speed and maneuverability of the farm tractor makes it an economical machine to move the bunches on shorter skids. Over the past five years, he has skidded over two million board feet of logs with this machine. However, for rough terrain and longer distances, he uses the rubber-tired skidder. After limbing and bucking, the stems are sorted and decked according to the end product. Operators in our area have used a variety of machines for sorting and decking; including front-end loaders, skidders and grapple loaders. The limbs and tops can then be allocated to either a burn pile or to a mobile chipper.

2/ The use of trade, firm, or corporation names does not constitute an official endorsement of or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

The third step of the operation consists of directionally handfelling timber too large for the Feller-Buncher. In a coordinated logging system, it is possible in the first two steps to prepare openings for this timber so damage to the remaining trees is minimized. It is also helpful to equip the grapple skidder with a small winch and line to reach the occasional inaccessible tree. These larger trees are also skidded full-length to the landing for processing.

In addition to the management benefits of a slash-free stand that may be easily re-entered for future harvest, this coordinated logging system has a distinct advantage for the optimum use of forest residue. The raw material is concentrated at a central landing where it can be segregated into a variety of end products, chipped or (as is currently the case) burned. Even burning is facilitated because the large hot fire will consume green material with a minimum of air pollution. I have described this logging system in detail because it is essential to the discussion of product allocation which follows.

ALLOCATION OF PRODUCTS

Once the forest residue is collected at a landing, the landowner or logger can make allocation decisions. In our situation, the use of the previously described logging system resulted in large accumulations of material so we attempted to utilize rather than burn it. As mentioned earlier, we have had to develop a variety of markets which are based on the size and condition of the residue.

Class 1 Dead Small Sawtimber

The first class of material includes trees which have been dead for up to three years and are 9 to 13 inches d.b.h. I consider green trees in this size range and larger as commercial timber, although I am sure that many of you mill people consider "bull pine" in any size class as residue. Strictly speaking, we do not view dead small sawtimber as residue because it is the "bread and butter" of our operation and the successful marketing of this material allows us to utilize the other classes of raw material. This timber has been allocated to two primary markets: dimensional lumber and houselogs.

A basic and continuing use of these smaller trees is for dimensional lumber, mine stulls and railroad ties. However as Mr. Kohrt discusses in another paper in these proceedings, there are many problems associated with the processing of low-quality logs. As a potential remedy, the University of Montana School of Forestry is currently experimenting with a small, mobile dimension sawmill to determine production and recovery. It may be more profitable to saw the low-grade logs on site and haul finished or semi-finished products from the woods.

Profit opportunities for dead small sawtimber were enhanced when we developed a market which uses these stems in the round--primarily as houselogs. The major processor is the K & L Mill, which cuts the logs into two, three and four-sided cants for further manufacture by the Real Log Home Company of Missoula. The Real Log house uses sections of logs, rather than full-length logs, in the walls thus enabling the effective utilization of ponderosa which as a rule has more taper than lodgepole. As structural differences between the species are not significant, the major obstacle in using blue-stained ponderosa for houselogs was its appearance. However, after a successful test-marketing period, Real Log began selling houses made from the beetle-killed trees and many people preferred the more rustic appearance of the stained logs. As a benefit to the manufacturer, the partially dried

logs are lighter and easier to handle, and the finished two and three-sided cants are more stable than cut green wood and not as susceptible to twist and warp. From an economic standpoint the dead logs are worth approximately the same ($2.40 to $2.50 per stem delivered to the mill) for dimensional lumber or houselogs. However the lower cull percentage in the round log application makes it a more profitable market.

We have also sold dead ponderosa to builders of traditional saddle-notched log houses and to one individual who lathes the logs prior to assembly. Another carpenter cut and hand-planed four-sided cants from the blue stained logs for use in post-and-beam construction. The structural members were left exposed and lent a very colorful and pleasing appearance to the finished building. We also attempted to utilize recently dead trees in the 12-to 17-inch d.b.h. range for utility poles. However, after a few test loads, we abandoned this application because of the high cull percentage. In general these specialty markets offer a much higher return per stem, but the demand is too limited for any sustained operation.

Class 2 Pole-sized Stems

The primary allocation of the second class of residue--green and dead stems in the five-to-nine-inch d.b.h. range--is to posts and rails. Because this market in western Montana has been traditionally dominated by lodgepole pine, it was once again necessary to provide both free material for testing and also information on structural characteristics. The post-yard operator had to experiment with treat schedules to ensure that the dead material would meet standards without costly overtreating. He overcame initial consumer resistance by full-treating the posts and selling them in eastern Montana and the Dakotas where people were more accustomed to ponderosa pine products.

We have used two different methods to manufacture this material into posts and rails. In the first instance the pole-sized trees are decked at the landing, and then as time is available, the stems are bucked to length and hauled to the post yard. In this system, the net return per stem is approximately $0.65 (excluding felling and skidding costs) but it is time-consuming for the crew whose time can be more profitably spent removing commercial logs. To reduce manufacturing time, we also haul the material to the post yard in tree lengths which are cut to a 3½-inch-top diameter. The operator using a conventional logging truck has averaged 243 stems per load for 6 loads. The average value per stem delivered to the mill has been approximately $1.00 ($0.43 after deduction for loading and hauling). The full-tree system, although net return is lower, requires less landing area and allows the crew to concentrate on larger trees. It appears that a combination of the two systems may be the most efficient.

We also attempted to utilize these small trees with a portable studmill. On an experimental basis, we cut 20,000 board feet, lumber tally, of studs from the dead ponderosa pine. Although the lumber was generally of low quality, it was acceptable; and use of the tree shear did not require additional trim allowance. However after the initial test, we did not pursue this market because the taper of ponderosa reduced overrun to an unacceptable and unprofitable margin. It was also difficult to dispose of the mill wastes.

Class 3 Small Trees, Limbs and Tops

Usually this class of residue is burned at the landing. However, in anticipation of a pulp/chip or hog-fuel market, we have experimented with three different machines that will chip this material in the woods. The first machine, a Model 24 Morbark, produced chips that with further screening would be suitable for pulp, or as hog-fuel if left unscreened. At the end of the test we felt that the high initial cost, high operating expense and lack of maneuverability would preclude using a model of this size for small stems. The second chipper was a small, trailer-mounted model, similar to those used by tree-removal and utility companies. This machine was not practical because it was very slow and labor-intensive, and would not process material greater than five inches in diameter.

In March 1979 we experimented with a medium-sized machine that appears to be suitable for our operation. This was a Model 12 Morbark, which is capable of chipping 11½-inch diameter trees, yet is small enough to be moved in the field by a farm tractor. Based on an average of 120 tons, the net chipping time per ton, for trees four inches in diameter and smaller, was 5.75 minutes. For trees that would not make a 16-foot houselog and from tops of larger trees, the Model 12 chipped a ton of residue every 4.13 minutes, based on a total of 103 tons. Potter fed the chipper directly with his skidder from material pre-bunched in the woods. The average skidding distance was 250 feet, with the longest skids ranging out 250 yards. By selecting turns from a variety of distances, he was able to efficiently feed the machine with the one skidder. On a three-acre test plot, 3,000 board feet of houselogs and 47.6 tons of chips were removed per acre--all dead ponderosa pine.

This small study was designed to test the ability of the machine to produce chips at the landing using the logging system described. It was not actually a cost feasibility study. However, when we chipped the post-sized trees, it took an average of 10 stems to produce a ton of chips. If these stems, which are currently worth from $0.40-$0.65 each at the landing for other products, were allocated to chips, the landowner would have to receive approximately $5.50 per ton of chipped material. The landowner, however, can realize other values from whole tree chipping chipping. He would not have to process the trees at the landing and could log pine stands when fire dangers and potential insect build-up may otherwise preclude operations thus gaining additional profits from a longer operating season.

The landowner will also have to consider the management implications of full-tree logging and utilization on log-term site productivity. Studies are currently underway at the School of Forestry by Dr. Nellie Stark to determine if full-tree logging and the subsequent removal of slash may be detrimental to the forest nutrient regime. If this proves to be the case, the chipped material (or a portion of it) could be returned to the woods to replenish lost nutrients.

Class 4 Older Dead Trees

The last class of residue includes trees of all sizes that are unsuitable for other products because of excessive check rot, deformity and so forth. With the exception of the chipper studies, we have either burned this material or sold it as firewood. Presently we are marketing the stems larger than six inches d.b.h. by the truckload to a commercial firewood dealer. Based on the limited number of tree-length loads sold to date, the return per stem at the landing is $0.65--a value higher than that realized for posts and rails.

CONCLUSION

In conclusion, to successfully utilize forest residue, the committed landowner must use a coordinated logging system and be willing to develop a variety of markets. Even when these factors exist, residue utilization is only marginally profitable and is subsidized by the harvest of larger trees. By working with this material now, we plan to be better prepared when large-scale opportunities arise.

FOREST MANAGEMENT IMPLICATIONS OF IMPROVED RESIDUE UTILIZATION: BIOLOGICAL IMPLICATIONS IN FOREST ECOSYSTEMS

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ABSTRACT

Various forms of residue provide parent materials for the development and function of the organic mantle of forest soils. Organic matter provides either the environment or the energy source for a variety of microorganisms which are critical to continued site productivity. Of the many organic materials added to forest soils during a stand rotation, the woody component is, in many respects, the most important. To protect the productive potential of a forest soil, a continuous supply of organic materials must be provided.

Intensive wood utilization may interfere with the supply of appropriate quantities and types of organic materials being cycled on certain sites. Providing adequate organic supplies could, therefore, impose constraints on harvesting intensity and residue utilization standards. Current research has provided some insights into this potential problem in the northern Rocky Mountains. Research indicates no serious shortage of organic residues with current management practices on productive sites in the northern Rocky Mountains. Substantial increases in utilization intensity, extremely hot wildfire, or excessive site preparation could reduce stand productivity, particularly on harsh, cold or dry sites.

KEYWORDS: forest soil, organic reserves, microbial activity, ectomycorrhizae, nitrogen fixation, non-symbiotic, intensive utilization

INTRODUCTION

As practicing biologists, forest managers intuitively realize that wood and other tree organic components may have specific functions in forest ecosystems. Since the economic and technical practicability of using intensive or near-complete utilization of on-site fiber appears imminent, we investigated the potential for such practices to interfere with the critical roles woody residues and other organic materials might have in the function of forest soils. We discovered that various organic residues--especially wood--do have integral and sometimes critical biological functions in forest soils of the northern Rocky Mountains.

BIOLOGICAL ROLE OF RESIDUE

Residues have many physical and chemical characteristics which make them important to biological processes in forest soils (Larsen and others 1980). Dead plant bodies tie up substantial quantities of nutrients, tend to retain large quantities of moisture, and can restrict air, sunlight and large animal movement (USDA For. Serv. 1980). Buried in the soil profile, organic detritus improves aeration, tilth, and moisture retention, thus protecting the soil from compaction (Lull 1959). In the form of accumulated surface debris (bound carbon), residues represent fuel for wildfire, an important force in the development both of northern Rocky Mountain forests and of the soils in which they grow (Habeck and Mutch 1973; Harvey and others 1976a).

The chemical energy bound in the carbon compounds of plant residues fuel a number of important biological activities. Some organisms supported by residues function only as nutrient and organic matter recycling agents. Others represent major factors in the development of soils (decay fungi), plant nutrition (N-fixation, mycorrhizae) or the spread of insects and diseases (USDA For. Serv. 1980).

Perhaps most important among the organisms supported by forest residues are microorganisms that serve critical roles in soil development and plant nutrition. Decay fungi, for example, have four major roles in soil development: 1) to break down plant bodies and recycle carbon; 2) to release nutrients bound in plant bodies for use by living plants; 3) to contribute energy to nonsymbiotic N-fixing bacteria, which increase soil N supplies; and 4) to control the character of the soil organic matrix. Decay fungi have a unique ability to break down the complex molecular structures of wood and other organic materials, leaving a lignin matrix that serves as a building block for soil humus. In the organic matter breakdown process, some of the energy released is diverted into fixation of atmospheric nitrogen (N) through the action of bacteria associated with the rotting materials (Larsen and others 1978).

Forest soils of the northern Rockies usually contain five easily recognized profile components: 1) the litter layer, consisting of recognizable plant litter (leaves, etc., usually designated as the O_1 horizon); 2) the humus layer, consisting of extensively decayed and disintegrated organic materials sometimes mixed with mineral matter (usually designated as the O_2 horizon); 3) decayed wood, consisting of the residual lignin matrix from decaying woody material that has been incorporated into the soil profile (we have designated this the O_3 horizon); 4) charcoal, or extensively charred wood mixed in soil as a result of historical fire activity (we

have designated this the O_4 horizon) and 5) the mineral soil base material (we have designated this the M horizon). The surface 5 to 10 cm of the mineral layer usually has a small amount of incorporated organic material, normally less than 10 percent. Each of these horizons, or components, supports specific microorganisms that improve the quality of the soil as a medium for plant growth.

The amount of organic material in our forest soils is limited. Usually organic matter makes up less than 15 percent of the top 15 inches (36 cm) of our soils. Nevertheless, this organic matter can support up to 95 percent of the ectomycorrhizal activity that occurs on roots of existing tree crops (fig. 1). Ectomycorrhizal fungi are symbionts particularly important to the growth and survival of conifer species in infertile forest soils (Hacskaylo 1973).

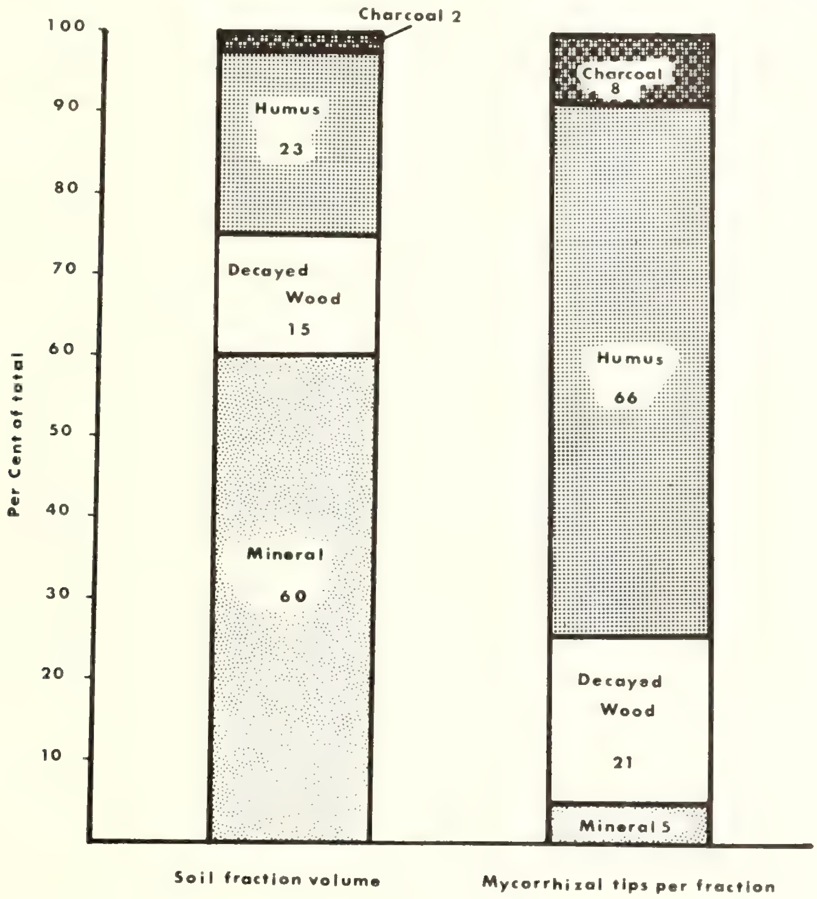

Figure 1.--Soil fraction volume (in percent of the top 15 in (30 cm)) and percent of active ectomycorrhizae found in soil core samples from a research plot in a 250-year-old Douglas-fir/larch forest in western Montana, Abies lasiocarpa/Clintonia uniflora habitat type (Harvey and others 1976).

Free-living soil N-fixing bacteria depend on the carbon components of soil organic matter for energy. Although mineral soil supports a substantial amount of N-fixation, it probably does so because of the organic matter it contains. On a weight-to-weight basis, free-living N-fixers are much more active in organic soil horizons. The rate of activity is normally between 5 and 10 times greater in organic versus mineral soil horizons (Jurgensen and others 1979, 1980).

Residue and residue-derived soil organic matter can also harbor harmful microorganisms. Woody litter, stumps, roots and other materials may contain inoculum that can spread and intensify various tree diseases, particularly root pathogens (Nelson and Harvey 1974). Residues can also harbor harmful insects that can serve as focal points for future damage to forest stands (Fellin 1980). In addition, accumulations of residue and soil organic matter can provide cover and nesting sites for various small animals that feed on young trees (Gruell and Ream 1980).

ACCUMULATION AND CYCLING OF RESIDUES

As pointed out above, residues in the form of various kinds of organic matter in or on forest soils, can have either or both positive and negative biological impacts on forest ecosystems. The balance between good and bad depends on a host of factors, including site history, type of vegetation, existing soil structure, and presence of pests. In other words, organic matter must first be produced if it ultimately is to be incorporated into the system. Secondly, this organic matter must be converted into a functioning soil component. The processes of decay and physical oxidation (fire) convert this biomass into appropriate chemical constituents. There is a balance between the processes of tree growth and the decay and disintegration of the resultant residues. In the northern Rockies biomass production usually exceeds rates of decay and disintegration (Olson 1963). Although excess materials (fuel) are partially recycled by periodic fires, decayed soil wood can persist in northern Rocky Mountain soils for periods of at least 500 years (unpublished data).

There are sites where fire cycles are frequent or rare; where organic materials accumulate and where they do not; where the soil organic structure is well developed and where it is poorly developed. Such characteristics reflect site specific differences in timing and amount of precipitation and soil temperature regimes, which in turn affect production and recycling processes (Harvey and others 1979b). Since moisture-temperature balances are an inherent part of the historical development and evolution of our forests, it seems reasonable that the function of various amounts and types of organic materials would change according to the specific ecosystems.

A CHANGING ROLE FOR RESIDUES ON DIFFERENT SITES

There is an obvious effect on the role of residues from sites that have a history of insect, disease, or animal predation problems. Residues have the potential to increase damage caused by these organisms and possibly contribute to further spread of the problem. Even if problem organisms are not causing damage, residues may still contribute to development of damage by providing an environment that attracts insects or animals, or that supplies inoculum sources of pathogenic fungi.

Although less conspicuous, the role of residue in supporting beneficial microorganisms also is subject to change. This is the case with both ectomycorrhizae and nitrogen fixation. For example, when we compared relatively harsh, dry sites to more moderate, moist sites, we found the relative importance of organic materials in supporting beneficial microorganisms was substantially higher on the harsher sites. This was particularly true of woody materials in supporting ectomycorrhizae (Harvey and others 1979a, 1979b). We also found the extent of microbial activity on our experimental sites reflected the sites' productive capacity (Harvey and others 1979a; Jurgensen and others 1980).

Soil organic materials supported a larger portion of the beneficial activity than mineral soil on harsh sites where the potential for such activity was lower (fig. 2). This represented a domino effect--a greater portion of lesser activity depended on the organic materials that harsh, cold or dry sites could not produce in volume. Harshness leads to a low productivity potential.

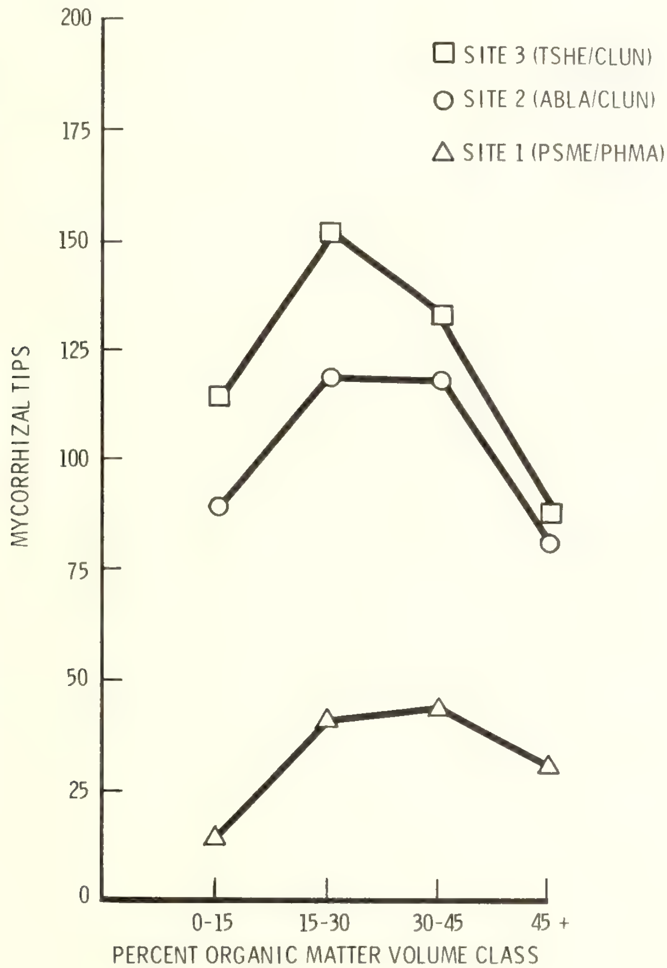

*Figure 2.--The average number of ectomycorrhizal root tips per liter of soil from three forest sites in western Montana.**

**Some samples are grouped into classes according to their organic matter volume. Sites are as follows: site 1--warm, dry Pseudotsuga menziesii/Physocarpus malvaceus habitat type; site 2--cool, moist Abies lasiocarpa/Clintonia uniflora habitat type; site 3--warm, moist Tsuga heterophylla/Clintonia uniflora habitat type. See Pfister and others (1977) for additional details on habitat types.*

RISK OF TOO LITTLE, TOO MUCH, OR THE WRONG KIND OF RESIDUE

Biomass production in northern Rocky Mountain ecosystems is at least partially dependent on the ability of soils to support N-fixing and ectomycorrhizal organisms. The ability of soil to support these organisms can, in turn, be largely dependent on the presence of organic matter. Inherent to such interrelationships is the obvious fact that total or near total loss of soil organic reserves is likely to reduce productivity in terms of tree growth. Less obviously, these interrelationships offer an answer to the question of how much and what kind of organic reserves our ecosystems require.

Our research on the ecology of ectomycorrhizal activity in forest soils of the northern region has provided some initial data on levels and types of soil organic matter required to support modest levels of ectomycorrhizae in mature ecosystems. Since the behavior of beneficial microbes such as non-symbiotic N-fixing bacteria is similar to that of ectomycorrhizal fungi, ectomycorrhizal activity provides a useful "barometer" for assessing microbial health of soil systems.

By dividing soil samples containing ectomycorrhizae according to quantity and type of organic material in which they reside, and then relating organic matter volume to ectomycorrhizal activity, we were able to derive a set of data representing initial parameters to the question of how much is enough. We feel organic matter is usually deficient when it occupies an amount of less than 15 percent of a 12-inch (30 cm) soil core. No additional benefits were realized from organic matter levels in excess of 45 percent of the core (fig. 2). These percentage figures are equivalent to a continuous surface layer 1.8 inches (4.3 cm) and 5.4 inches (13 cm) in depth, respectively.

In the Rocky Mountain ecosystems we sampled, the ratio between humus and soil wood usually approximated 1/1. As proponents of increased wood utilization, however, we are most concerned with the larger woody materials. Due to the infertility of Rocky Mountain forest soils, we oppose removing high nutrient content foliage or small residues in any case (DeByle 1980, Stark 1980). The nutrient content of tree boles is much lower and, therefore, their removal represents a lesser hazard (Stark 1980). By conservatively assuming that most soil organic matter required for future stand growth must be derived from woody residues, we can calculate a residue loading level below which long-term productivity of the soil may be impaired.

By assuming a 40 percent loss of volume from the time a log becomes fresh residue to when it begins functioning as a soil component (based on field observations), and by converting the 45 percent soil organic matter content figure noted above to volume, then to residue weight, we calculate that 10-15 tons per acre as a continuous supply of fresh residues (less than 25 years old) should be left after any cutting, burning or other site treatments to maintain soil organic reserves. We further suggest that since larger volumes are generally more effective, that this tonnage consist primarily of larger residues, perhaps 6 inches in diameter or larger. Because Douglas-fir (*Pseudotsura menziesii*), western white and lodgepole pines (*Pinus monticola* and *Pinus contorta*) appeared more frequently in the soils we studied, despite the presence of other species on the sites, we recommend that residues of these species make up the bulk of the material left on harvested sites.

RESIDUES AS A MANAGEMENT OPPORTUNITY

Forest residues provide a major tool for manipulating harvested stands. In many ways residue manipulations represent the only practical management tool available for mitigating physical effects of harvesting systems that remove most of the standing tree crop, or effects of harvest and post-harvest procedures that require extensive soil disturbance (Hungerford 1980).

Residues provide a barrier from wind, sun, and erosion; and they can control large animal movement and feeding patterns. Residue removal can minimize the propagation of insects, diseases or small animal problems, but their continued presence can provide a major input to soil nutrient quality through support of benefical organisms (USDA For. Serv. 1980). Resolving potentially complex trade offs in order to successfully manage residues to achieve one or more of the above objectives will require careful examination of individual stands. Knowledge about existing site residues, about residues and soil disturbances caused by harvest method and silvicultural prescription, and about soil organic reserves and past pest problems will provide a good base. With such information trade-offs can be determined, and residue inventory specifications and utilization or prescribed fire standards can be established to elicit the most beneficial biological response from the ecosystem.

Perhaps most beneficial among the positive results of residue manipulation is the opportunity to enhance soils as a medium in which to grow trees. Without an adequate soil base, the potential for a good tree crop simply does not exist, whether or not other important factors, such as seed availability, rodents, insect, disease or grazing damage, also exist. One exception would be a situation where a soil could use additional organic reserves, but the available materials are infested with insect or disease inoculum. In such a case it may be better to remove or burn the infested residues and accept the added time required to rebuild organic matter levels. For the soil wood component, this may require periods well in excess of one hundred years.

CONCLUSIONS

Current research indicates potential hazards and opportunities from the practice of intensive fiber utilization in northern Rocky Mountain forests. The need to maintain minimum reserves of soil organic matter may constrain utilization practices but probably only in harsh, cool or dry ecosystems or in ecosystems with a severe fire or intensive logging history.

Recognition of the important role residues play in northern Rocky Mountain ecosystems will help avoid site degradation caused by excessive fiber removal. Using a reasonable biological perspective to guide our residue manipulations would represent an opportunity to maintain or even improve our harvested sites and their soils as a firm foundation for future forestry.

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THE IMPLICATIONS OF IMPROVED RESIDUE UTILIZATION ON TIMBER SALE ACTIVITIES

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ABSTRACT

Improved residue utilization on timber sales requires new and innovative economic and practical approaches on timber sales. Varying uses, resource needs, and economic limitations complicate the land manager's task of salvaging this material.

KEYWORDS: residue, utilization, economics, complicate

My purpose is to discuss some of the implications of improved residue utilization on timber sale activities. It would be convenient to simply equate that subject with the day-to-day business of harvesting National Forest timber. However, it is not quite that easy. In many respects it is a whole new ball game.

For that reason my comments on a residue utilization program will be directed toward the economic and practical side of getting material moved with a minimum of problems for both the seller and the buyer. They are also directed principally toward the removal of dead timber, rather than to tighten utilization specifications on otherwise merchantable trees.

First, I must digress a bit. Each time a land manager decides to offer a timber sale, he presupposes he can sell it. Otherwise he accomplishes nothing. While successful sales are the general rule with standard timber and products, a residue utilization program can easily become an administrative nightmare. Ideally, the land manager is not supposed to let economics influence his environmental ethics. Yet in the business of residue utilization, he must do precisely that!

I am not here to recommend national policy to you. Realistically, however, residue is residue only because economics say so! There are most certainly methods of improving the economic picture, but in many ways, there is no golden fleece. With government timber, and perhaps with private stock, residue

utilization depends on how much we are willing to pay for it. We have many options, but in general, each one costs the taxpayer money, at least in today's dollars.

We must also be careful not to restrict our thinking to timber sales themselves. It may be necessary for the government to pay the user, instead of the user paying the government for removing this material. This might be done through land management contracts with salvage provisions. It may be in the form of augmentation, supplementation, or outright construction of road access to the material. Perhaps a less painful way to make ends meet would be through tax incentives to industry. No matter what, if we want to move more residue, the user must somehow gain by his participation, and the government must ultimately pay for any deficit.

THE NATURE OF RESIDUE UTILIZATION SALES

A number of points must be considered in preparing residue utilization sales. First, a sale of residue by itself is usually a sorry situation. The operation which left the residue is the basic mistake, and the residue sale only the consequence. Removal of the only the high-value element of a stand, such as green timber or cedar salvage, may very well leave behind an economically impossible residue removal chance. The need for advance planning and integration with regular sale programs is obvious.

At first thought complete utilization sounds simple to specify--just take everything down to a minimum size. Let me assure you a deadwood contract is much the opposite. Describing several products, many of which overlap, in a way which is practical and nondiscriminatory to all potential buyers, is a difficult task. It seems each buyer has a different set of product specifications he wants the land manager to use, and nearly all of them result in incomplete utilization. No matter what choice is made, someone is unhappy.

A partial answer to this is a wide variety of sale sizes with varying specifications. Perhaps specifications should not be ironclad, and permit bidders to propose their own utilization standards along with their bid. It is easy to see how such a program would give a manager headaches and a good deal more work.

Measurement of residue is another bugaboo. Conventional scaling is often meaningless. From the government's standpoint, an easy remedy is sale by weight. I am convinced that weight is the best common denominator, but do not overlook the plight of the user who has to deal with inventories, payrolls, and production targets.

Even then the land manager cannot simply ignore end-product estimates. Since Forest Service timber appraisal methods are usually based on traditional measurements such as board feet, conversion to weight in the appraisal process is often troublesome.

One more generality which may be useful is to recognize that yarding unmerchantable material (Y.U.M.) is a key part of the battle. Y.U.M. with optional removal will accommodate industrial specialities, but still permit subsequent resale or use by others of the remaining material. This method has proven merit.

Still, complete utilization is seldom a realistic goal. One simply cannot and probably should not get it all. Even in small-diameter species such as

lodgepole pine, only a small percentage of the total bulk is in small diameter logs and short pieces. You can often afford to specify a larger top diameter or a longer log length on dead material, and still get 90 percent of the volume. Overly restrictive standards can very easily devastate an otherwise good offering.

LAND MANAGEMENT IMPLICATIONS

Residue utilization proposals often present uncomfortable situations to the land manager. The real stickler is that once a tree dies, the alternatives dwindle to either cutting it or leaving it. Since total utilization is not a realistic objective, managing residues becomes a pick-and choose proposition. What works well in one situation may be a complete failure elsewhere. Such things as regenerative systems, slash disposal methods, esthetics, wildlife needs, and fuels management are only examples of the complexities.

All this adds up to a time-consuming and burdensome addition to the land manager's regular work. The temptation is, of course, to go on as always and let improved utilization fall by the wayside. In some situations this would matter little, except in the size of the slash piles. At other times, wood utilization problems are inescapable, such as in the Targhee National Forest. In any case, the land manager must display initiative and imagination if meaningful changes are to be realized.

I also suggest that we have at times created our own residue problems. How often have we cut through a stand which is 60 or 70 percent defective, and then wondered what to do with the residue? Perhaps we should have stored that wood on the stump until technology and economics had caught up with us. Wouldn't we love to have back what we used to waste, even five or ten years ago?

ECONOMIC GUIDELINES

The subject of waste wood economics is a two-edged sword. As I mentioned earlier, we need to be conscious of the tax dollar. On the other hand, we must offer a profitable venture to prospective buyers. There is no better way to thread this needle than to involve industry all the way. Alternatives are often abundant, if we will only search for them.

You will commonly find that road access is the key to success or failure of a program. An already deficit sale simply cannot support the needed road construction. A well-planned access program supported by appropriated funds solves a myriad of problems and affords many more options to the land manager.

The same principle applies to reforestation. Although the Chief's policy normally requires that reforestation costs be included in minimum charges for timber, this cost can be a backbreaker. It can also be administratively overcome!

The October, 1979 Journal of Forestry contains a thought-provoking editorial on salvage sales in the Rocky Mountain states. It seriously questions the propriety of salvage on marginal sites requiring these high road development and reforestation costs. Indeed, the National Forest Management Act mandate to identify marginal timber sites could very possibly change the entire picture.

Still, we may be wise to look somewhat beyond the end of our noses in evaluating costs and benefits. The eventual cost of high intensity wildfire may make current investments in salvage efforts seem insignificant.

THE LAND MANAGER'S STRATEGY

If I had to condense my advice to both land managers and to industry on utilization of residues, I would have to simply say "hang loose". Maximize the involvement of all parties. The buyer and seller should regard each other as equal partners in this game. After all, if one loses, so does the other. Don't worry about being accused of "being in bed" with one another. You'd better be, if you expect to succeed! Search for new ideas, but be wary of big, new deals. Try instead to work with established markets and local industrial outlets. Expect a strong resistance to change. I can assure you that you will encounter it from all sides.

Last of all, don't ever say it can't be done. If you do not take positive steps toward improved utilization, you will soon find that the good old days are gone, and you are left behind. There is no middle ground.

AN ECONOMIST'S PERSPECTIVE OF RESIDUES

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ABSTRACT

As the values of wood products increase, there are more economic opportunities to utilize residues. This is true both for dead-and-down materials and for previously unharvested stands which, together, make up the potential economic residues resource. A variety of research efforts are developing the information and technology necessary to take advantage of these opportunities. The key to minimizing future residues problems is to fully integrate residues considerations with overall forest resource planning.

I will speak to residues from the perspective of an economist, and most particularly from the perspective of a Forest Service economist working in Washington, D.C. From that vantage point, it seems apparent that:

--the values of wood products are increasing,
--increases in values are leading to fewer residues,
--the key to minimizing new management problems is to plan eventual residue treatments before the residues are created, and
--carefully directed research will help managers deal with potential residue problems.

I define forest residues as forest trees and parts of trees that are available for conversion to marketable products but are not now being used. This is an economic rather than a traditional definition, for the economic question is whether a larger portion of the available wood fiber that is grown can be used. Both in the Rockies and in the eastern United States, relatively low-value stands are currently major components of economic residues. In the long-run, nature will ensure that unharvested trees become indistinguishable from other kinds of "residues".

VALUES OF WOOD PRODUCTS ARE INCREASING

Others have presented statistics that indicate there are large volumes of both standing and down softwood and hardwood residues in the United States. In contrast, there are essentially no residues of any kind in the closely tended stands of Europe. A major reason for this difference is, of course, economics. A unit of wood is more valuable in Europe than here. As values and prices go up, a larger share of the available quantities of any commodity, including wood, will be used.

The most obvious evidence of increasing wood values in the northwest is the increasing average bid price for public stumpage. Prices of $400 per thousand board feet are no longer uncommon for coastal Douglas-fir. Recently, the Willamette National Forest in Oregon sold 10 million board feet for over $750 per thousand. The Tahoe National Forest in northern California recently sold 5-1/2 million feet of mixed ponderosa and Jeffery pine for $590 per thousand. In this Region, bids for ponderosa pine have approached $200 per thousand. But the cyclical, boom-and-bust history of the timber industry requires caution in projecting a continuation of extraordinarily high prices for wood products and for stumpage.

Indeed, housing starts are currently decreasing. It appears there will be a decrease from the 2.0 million starts of 1978 to about 1.7 million this year, and projections suggest there will be a further decrease in 1980 to about 1.4 million housing starts. These decreases have been primarily due to historic high costs of borrowing money. However, we know there is an accumulating and unsatisfied demand for housing by those born since the second World War which will peak in the late 1980's. In spite of a growing trend towards close-in multi-family dwellings, greater volumes of wood will be required to meet these demands. There most likely will be another expansion in housing starts--in part, as a result of deliberate national policy. The nation-wide trend towards families with two wage-earners and a willingness to accept mortgage interest rates of 12 or 14 percent, which have long been common in other countries, will produce the necessary purchasing power.

Demands for other uses of wood will also be high. For example, rising domestic demands for pulp will increase the competition for softwood fibre, including that which is currently fabricated into solid wood products.

One other piece of evidence may be of interest. In Vermont, which is at the end of the fuel oil pipeline, perhaps half of all homes are completely or partially heated with wood. In November the Washington Star reported that more than 1-in-20 families throughout the Nation now have woodburning stoves. Aside from creating a haze over towns like Missoula, these demands have driven up the price of fuelwood. In Missoula, a full cord of firewood will be delivered for about $45. In Washington, D.C., a face cord costs about $100. While such prices seem extraordinary, the Department of Energy estimates $100 per cord will be a good buy when the price of home heating oil reaches $1.00 per gallon. Fuel oil has now risen to about 85 cents a gallon in Washington.

In total, in spite of market fluctuations, there are numerous indications that demands for wood and wood products will remain strong for the forseeable future.

INCREASED VALUES ARE LEADING TO INCREASED USE

Increasing demands and prices for wood have led to responses on the supply side. Until perhaps 30 years ago, the principal response would have been to move timber harvesting into previously unexploited areas. Now new sources of wood products must be developed from residues remaining after harvesting and from forest stands previously passed over, either because those stands were uneconomic to log or because they could not be logged without posing the danger of intolerable impacts on other forest values. Indeed, the Missoula research program sponsoring this Symposium has been directed towards determining the extent to which such potential resources or residues might be transformed into actual resources and wood products.

The starting point for determining how more wood might be produced has been to focus on removing a larger share of the total wood from harvested areas. The relative benefits and costs to the landowner and stumpage purchaser are both critical. On the National Forests and some other lands, the "landowner's" concern is expressed through contractual standards that define how logging is to be done.

A number of published studies have dealt with the economic realities of physical opportunities to utilize residues in particular situations. For example, Snellgrove and Darr (1976) discussed the prospects for producing lumber from cull logs in the northwest. This type of study is particularly important because a side effect would be a reduction in present accumulations of residues that pose substantial management problems. In the southeast, Goldstein and others (1978) examined possibilities for utilizing low-grade hardwoods. Given the millions of acres in the east containing such stands, their economic utilization would provide substantial benefits to landowners and make future stocking with better quality trees more likely.

The formulation of standards that specify how logging is to be carried out and, more particularly, that define the wood that must be taken and the treatment of residues on the National Forests has generated continuing controversies. On one side are arguments that almost any "non-market" standards impose unfair economic burdens on timber operators or require loggers to waste their time or waste dollars that should go to the Federal treasury. On the other side are arguments that standards are necessary to ensure that all resources are adequately protected and that the forest retains its long term productive capacity.

As John Robatcek of this panel discussed earlier, creating the ideal sales contract to deal with residues is a complex business. In general, that set of standards is sought that will yield as high a volume of products as possible, that will realize the ecological benefits of leaving residues on the ground, and that will minimize the problems caused by too many residues, including:

- --the risk of wildfire or the subsequent need for controlled burning or other treatment of residues,
- --damaging ecological effects of residues,
- --impediments to management activities or to the long-term productive capacity of the forest,
- --physical barriers to recreationists, and
- --the creation of aesthetically unappealing scenes or a basis for a public perception that wood is being wasted.

The importance and difficulty of achieving these objectives have been discussed elsewhere in the Symposium, but one point is worth restating here. Some have argued that subsidizing practices such as YUM yarding (that is, yarding unutilized

materials) is uneconomic. To the extent that leaving residues where they fall requires later corrective activities, an initial subsidy may, in fact, be the less expensive course to follow (Adams and Smith 1976). The continual refining of such practices and the determination of just when they are most appropriate will become increasingly important.

Another approach on the National Forests has been to reexamine the possibilities of harvesting timber from areas that had been judged earlier to be uneconomic to log or where substantial impacts on other resource values were feared. In the early 1970's the Forest Service proposed a major effort (termed the FALCON program) to define ways to harvest timber from such areas. The basic components that were to be included in that effort were subsequently incorporated into the programs now centered in Portland and in Missoula. These components include improving our understanding of the ecological and economic implications of alternative residue treatments and developing efficient logging systems for use in environmentally sensitive and relatively low-value stands.

Expectations of increasing stumpage prices, coupled with environmentally gentle and more efficient logging systems, will make it more feasible to harvest timber, for increasing margins between costs and product values increase the areas that are economic to log.

From the perspective of a public agency, expanding the areas where timber harvesting is practiced in the eastern United States also requires dealing with the special circumstances and frequently unsympathetic attitudes of numerous owners of relatively small areas. Nonindustrial private lands generally do not produce timber products at a level commensurate with the land's productive capability (U.S. Department of Agriculture 1978; for a dissenting viewpoint, see Clawson 1978). There is partial evidence that pine production from these lands might eventually decline. Particularly in the southeast, harvested forest lands are frequently not being restocked with pine and shifts of such lands to farming or to urban-related purposes continue. One area of emphasis of the Forest Service is to work with the States in developing comprehensive forest land plans and carefully defining how assistance might best be targeted to land owners.

The third approach to increasing the production of wood products has been to develop new techniques both to fabricate more products from a given supply of wood and to use currently underutilized materials in production. Speakers from the Madison Forest Products Laboratory have outlined the implications of new products technologies for residues. To me, it is self-evident that the United States will have to rely more heavily in the future on technological innovations to meet increasing demands for wood. We can afford neither the time nor the space nor the capital that would be required if we were to rely solely on growing more trees.

INTEGRATED PLANNING CAN MINIMIZE PROBLEMS

Existing residue problems are going to continue to be difficult and expensive to treat. Each option available to managers is likely to have some sort of undesirable side-effect. The trick is to make certain that all of the important benefits and costs are recognized before selecting a treatment (Bare and Anholt 1976). For example, the likelihood of losses to wildfires in untreated slash should be weighed

against the costs and smoke management problems of burning that slash. As our understanding of the ecological implications of residues increases, it will become possible to expand such considerations.

As the values of wood products increase and intensive management becomes more common, residues will gradually become less of a problem because there will be fewer of them. Frequent thinnings will capture mortality; trees will be harvested before they deteriorate; and utilization opportunities will increase.

More immediately, though, the key to minimizing future residue problems is to include planning for residues as an integral part of total resource management programs (Jemison and Lowden 1974). In the current round of land and resource management planning, the Forest Service is integrating planning for fire protection and management into overall Forest planning (Nelson 1979). The advantages inherent in moving from fragmented to holistic or over-all planning are also applicable to planning for residues management. Specifically, timber management planning should include explicit consideration of how residues that result from future harvesting and cultural activities will be treated, and the costs of those future treatments should be counted as costs when calculating whether timber production is economically and environmentally viable. Only through close integration of all planning can the most advantageous combination of management activities be selected to meet overall forest management objectives.

DIRECTED RESEARCH WILL CONTINUE TO HELP

It is much simpler to talk about the need for integrated planning than it is to do that planning. The new Regulations guiding planning on the National Forests call for enormous quantities of all sorts of information and analysis. At least in the short run, there will continue to be many professional judgments that can and should be criticized, although they will be based on the best information that is available (Committee of Scientists 1979). In the long run, directed research will provide a firmer basis for that planning, including planning related to residues.

There have been many references to the ways in which research and development activities are contributing to reducing residue problems. Major efforts include:

- --products research, which is directed towards developing new uses of wood fibre that cannot now be economically utilized;
- --development of logging systems, so that logging costs are reduced and environmentally sensitive sites can be harvested; and
- --determination of the effects of residues and of residue treatments on forest resource values.

Other kinds of research will also have some effect on residue utilization. Earlier I mentioned the usefulness of economic evaluations of converting residues to marketable products. Another need is to continuously update imaginary lines on the ground that separate those stands that are economic to harvest from those that are not. In a somewhat different vein, increased understanding of wildlife habitat needs and of wildlife values will make it possible to identify situations where commercial timber products might be harvested as a by-product of habitat management, even though such areas might not otherwise provide economic harvesting opportunities.

I do not intend to imply that every stand should be harvested if economic requirements can be met. Rather, within the context of the increasing values of wood products, carefully directed research can provide a firmer idea of what is possible. Then it is up to the planners and managers to display the production possibilities and their budget and tradeoff costs and to work with the States, organizations and concerned individuals to determine where and how products should be produced.

SUMMARY

There are substantial economic and environmentally acceptable opportunities to convert some portion of existing residues into marketable wood products. This is true whether the focus is on dead-and-down timber or on available but as yet unharvested stands. Opportunities to most significantly add to our national reserves of commercial timber seem to me to be greatest in presently unharvested stands, whether reference is to the millions of acres of lodgepole pine in the west or to the millions of acres dominated by hardwoods in the east.

The principal force at work that is leading to changing the potential resources of residues into actual resources is the increasing demand for wood products. This increasing demand has led to higher public stumpage prices and has stimulated reexaminations of sales procedures and applied research efforts.

Products research is leading to new markets for wood fibre that would otherwise become residues. Research such as that centered in Missoula is providing the information necessary to take advantage of those markets.

The key to minimizing future management problems associated with residues is to fully integrate explicit consideration of residue treatment alternatives into overall forest resource planning. Management decisions will then be more likely to be effective in producing the flows of wood products and the forest conditions that are desired.

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LEGISLATION AND POLICY INFLUENCING WOOD RESOURCE UTILIZATION

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ABSTRACT

The framework for harvesting and utilization opportunities for forest residues includes a number of long standing as well as recently enacted statutes. Air and water quality standards as set forth in additional legislation also have an affect on utilization opportunities. A further emerging factor pertaining to the harvesting and utilization of the forest biomass is our land base, and its availability. Recently the Senate has enacted a number of bills dealing with the question of timber economics.

KEYWORDS: residue utilization, forest policy, legislation

National materials policy has, as a framework for harvesting and utilization opportunities for forest residues, long standing as well as recently enacted statutes. Beginning with the now repealed Organic Administration Act of 1897, it has been made clear that the establishment of national forests is "...to furnish a continuous supply of timber for the use and necessities of citizens of the United States." The Monongahela court decision, which raised questions about the Forest Service's ability to sell timber unless it consisted of, "...the dead, matured, or large growth of trees found upon such national forests as may be compatible with the utilization of the forests thereon," caused Congress to enact the 1976 Forest Management Act. Originally Congress merely wanted to clear up the uncertainty created by the Monongahela issue; however, in the process a major piece of legislation emerged, supplementing and amending the historic Forest and Rangeland Renewable Resources Planning Act. During the legislative process leading to the passage of the 1976 Forest Management Act a wide range of forest users and other interested members of the public contributed. This interest has carried forward in the preparation of regulations, which it is fair to say, has been highly controversial.

It is useful for our purposes to quote from Section 3 of the 1976 Forest Management Act:

> Reports on Fiber Potential, Wood Utilization by Mills, Wood Wastes and Wood Product Recycling
> (c) The Secretary shall report in the 1979 and subsequent Assessments on:
> (1) the additional fiber potential in the National Forest System including, but not restricted to, forest mortality, growth, salvage potential, potential increased forest products sales, economic constraints, alternate markets, contract considerations, and other multiple use considerations;
> (2) the potential for increased utilization of forest and wood product wastes in the National Forest System and on other lands, and of urban wood wastes and wood product recycling, including recommendations to the Congress for actions which would lead to increased utilization of material now being wasted both in the forests and in manufactured products; and
> (3) the milling and other wood fiber product fabrication facilities and their location in the United States, noting the public and private forested areas that supply such facilities, assessing the degree of utilization into product form of harvested trees by such facilities, and setting forth the technology appropriate to the facilities to improve utilization either individually or in aggregate units of harvested trees and to reduce wasted wood fibers. The Secretary shall set forth a program to encourage the adoption by these facilities of these technologies for improving wood fiber utilization.
> (d) In developing the reports required under subsection (c) of this section, the Secretary shall provide opportunity for public involvement and consult with other interested governmental departments and agencies.

The Forest Service reports it is not ready with an assessment on this section at this time. The Resources Planning Act (RPA) Assessment is due to be submitted to Congress on January 22, 1980.

The Resource Conservation and Recovery Act, also known as the Solid Waste Disposal Act, was enacted in 1976, and it has caused concern in other industries because of the tentative regulations concerning the definition of hazardous waste. The implications in the wood fiber field are yet to be assessed, but because of the volume of fiber involved, as well as the diverse conditions, the impact on future use and planning is likely to be significant. Clean air and water laws will continue to have a major impact on all phases of forestry activities.

Energy programs and policy are developing rather rapidly as we grapple with our goal to be less dependent on foreign sources of oil. The Society of American Foresters in a study report of a task force titled Forest Biomass as an Energy Source, reports:

> Forest biomass--a renewable, versatile source of energy--can contribute the equivalent of approximately 9.5 quads to U.S. energy needs. (This value is exclusive of wood required for conventional products, but includes

aboveground biomass in net growth from commercial forests; mortality; and wood from land clearing, noncommercial lands, urban tree removals, and urban wastes.) If commercial forestland were fully stocked and intensively managed, biomass available for energy could increase to the equivalent of 18.9 quads by mid-21st century.

Biomass can be burned directly or converted to gas, oil, and char. Many forest industries, particularly pulp and paper manufacturers, now burn biomass for up to half their fuel needs. Blending biomass-derived alcohol with gasoline and using biomass in electrical generation may become practical.

The Federal Energy Administration (FEA) estimated in 1976 that annual energy use in the United States was about 75 quadrillion BTUs (or 75 quads), and that use in 1985 would be 98.9 quads. The agency also estimated that even under the most favorable conditions the United States cannot expect to gain more than six quads from emerging technology by 1990. A more realistic figure, it indicated might be two quads.

The emerging technologies evaluated by FEA included solar, geothermal, and synthetic fuels, but evidently excluded forest biomass. Energy currently obtained from wood is estimated at 1.1 to 1.7 quads. Members of the task force are confident that wood use for energy is increasing greatly, but we have no way of knowing the extent.

The comment that FEA evaluation excluded forest biomass potential reinforces similar comments, which emphasized the lack of attention by FEA to forest biomass potential. Despite the apparent lack of overall planning and assessment of this energy resource, there are many local and regional examples of increasing utilization of fiber for energy production. Studies and actual use of efficient wood stoves are being conducted by the Tennessee Valley Authority. The Eugene (Oregon) Water and Electric Board1/ uses large amounts of sawmill residue (hog fuel) for steam generation. Washington Water Power in Spokane has announced plans to build a wood fired generating plant. Pullman Swindell Company gave a presentation to the U.S. Senate staff last summer on their woodex pellet production from wood waste. More and more individuals are discovering the small chain saw and using spare time to gather firewood from a variety of sources.

Private companies have expressed interest in installing medium-size power generating plants using wood waste transported for up to 50-mile radius. The main problem in finalizing plans is the inability to reach agreement between the land manager and the power company over a long term supply of fiber at an assured price.

Pending legislation, including Synfuels, the promotion of the development of energy from agricultural commodities, forest products, and their wastes and residues, and rural energy conservation practices, and windfall profits (biomass property), which allows 20 percent tax credit, provide more substance for utilizing the energy potential of wood.

1/ The use of trade, firm, or corporation names does not constitute an official endorsement of, or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

Discussions with the staff members in the office of the Chief of the Forest Service in the past few years indicate they have about all the authority they need to develop a more comprehensive utilization of wood fiber for our energy needs. The key factors involved in moving ahead seem to be economics, and supply and demand. One has only to note the rapid change in the price of foreign oil--and our dependence on it--along with Middle East uncertainties to estimate where our energy situation is heading. A prudent person would have to consider all of our energy options, especially underutilized domestic options such as wood biomass.

Forest products industries continue to face the roller coaster effect of the price of money and its relation to the housing market. With the interest rates at 15 percent and up, some experts predict housing starts at a 1.1 million level next year. Should the price of lumber and plywood drop, mills having timber sales with super-high bid prices, and no cheap timber to mix, will have a tough time during this economic period. Since the only certainty in the lumber business is "uncertainty," the secondary source of wood biomass is likely to be affected. Our softwood imports have recently risen from 20 to 26 percent of United States consumption, which becomes more of a factor in our balance of payments.

There are other factors that have an effect on our land base, its availability, and the potential for utilization of wood biomass. The ultimate disposition of the Forest Service roadless areas (RARE II) is yet to be determined. The Senate recently passed a central Idaho wilderness bill, followed by an Oregon wilderness bill. The Idaho bill ordered RARE II lands in central Idaho released with report language, while the Oregon bill released remaining RARE II lands with statutory release language. It is likely the disposition of RARE II by the Congress still has a long way to go. This, of course, leaves a cloud over the planning process for wood fiber management.

A bill by Montana's Senator Melcher authorizes the recovery of wood residues in the national forests for use as fuel, and for conversion to use as petrochemical substitutes or wood products. This is done through the use of residue removal incentives. Residue recovery as a function of brush disposal, slash disposal, site preparation, timber stand improvement, and other relevant forest practices has not yet been thoroughly examined. Again, markets, costs, supply and demand, and other factors need to be thoroughly examined.

A current battle is emerging over timber economics, especially in the Northern, Intermountain, and Rockies areas of our National Forest system. Whether timber management can meet a test of 5 percent or 10 percent on investment is being challenged. This is another important factor in the fiber potential picture. Along with this goes road construction policy and other harvest requirements under the 1976 Forest Management Act and subsequent regulations.

The previous discussion suggests there are many conflicting and vague policies that address, or fail to, the opportunity for wood biomass management. We have a new challenge to be creative, and unique new markets to consider that are in the national interest. Wood biomass management can have a beneficial effect on tomorrow's forests. We hope we can develop a positive policy to utilize this opportunity.

WOOD PRODUCT AND MARKET TRENDS INFLUENCING RESIDUE UTILIZATION

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ABSTRACT

Of the four major potential uses for forest residues, none offer any immediate prospects for large scale use. We can expect cyclical demand for residues to supplement the material supply to the pulp and paper industry. The rising cost of energy could generate the greatest potential demand for residues.

KEYWORDS: residue utilization, residue markets

The potential markets for forest residues can be classified into four primary categories. They are:

A. Reconstituted panel products, such as particleboard.
B. Pulp, paper, and chemical extractives.
C. Post, poles, and house logs.
D. Fuel.

I will deal with each of these separately, and attempt to indicate some of the major influences which are expected to change the trend of forest residue utilization for each of the potential uses.

PANEL PRODUCTS

The particleboard industry, (which includes medium density fiberboard), grew up on wood residues. However, the basis is not forest residues, but mill residues. The difference is critical to the industry. Mill residues are convenient, already dry, and are available at a cost which is little more than the cost of transportation. The only problem with mill residue is that there is not much left. With uncommitted mill residue no longer available, it would appear that any growth in the production of panel products would need to be based on forest residues, as they are the least expensive alternative. However, the Northern Rocky Mountain region is at a distinct disadvantage compared to the rest of the country when it comes to making panel products of forest residues. Local markets are not large enough to absorb any significant increase in production, and the large markets are all quite distant.

It simply makes no economic sense to manufacture a product in the Rockies for shipment to the Mideast and East, when the same product could be made closer to the market. Forest residues are widely available, so there is no need to locate in the Rocky Mountains.

The cost of energy will also have a significant effect on the potential production of panel products, and for plants located in the Rocky Mountains, rising energy costs are a double curse. In addition to the direct energy consumption of manufacture, the panel products also use energy indirectly through the resins used to glue the particles together. The resin is produced from natural gas, so that the cost of resin is directly related to the cost of gas, which has about doubled in the past four years, and can be expected to continue to increase faster than other costs. Resin accounts for about one-third of the total cost of manufacturing particleboard, so that rapid increases in resin costs will place particleboard at a competitive disadvantage with other panel products.

As energy costs rise, so do transportation costs, which places an extra burden on reconstituted panel products from the Rocky Mountain area. Because of the long distances to market areas, an increase in transportation costs has a greater effect on products from this area than it has on similar products produced closer to the market.

All in all, the prospects for using forest residues to produce reconstituted panel products in the Northern Rocky Mountain region are not bright. There are many locations in the country which have adequate supplies of raw material, where the costs of materials and transportation are lower, so that we should expect any significant growth in the use of forest residues for panel products to occur not here, but in the South, the Midwest, and the Pacific Southwest.

PULP, PAPER, AND CHEMICAL EXTRACTIVES

Within the past two decades, the pulp and paper industry in the Northwest has shifted from a supply based primarily on roundwood to one based on mill residues. The shift has gone far enough that local pulp production and chip exports now use virtually all available supplies of chippable mill residues. There are, in the Northern Rockies, still a few small mills that do not sell chips, but they are scattered and isolated, and do not produce enough volume to provide a basis for an expansion in pulping capacity. Any increase in pulp production in the Northwest must be supplied from forest residues.

This is not to say, however, that the pulp and paper industry will be a major user of forest residues. The industry can be expected to use the cheapest material available to it, and that is not likely to be forest residues from the Northern Rockies. Existing mills that may require additional chips will go to forest residues close to them, and new mills will be built close to residues and markets. This means that the demand for forest residue chips from the Northern Rockies will come from existing mills in or close to this area. Since these mills are already well supplied with mill residues, it would appear that there is no impetus for using forest residues.

In the long run, there may be enough mill residues, but there are often short-run shortages, and we can expect to see these shortages filled with forest residues. There have been recurring patterns of periods when the demand for chips stays high while the output of lumber and plywood mills (including chips) is down, so that the pulp and paper mills are faced with raw material shortages. During these periods, there will be a demand for chips from forest residues, not only from local

mills, but from the surrounding area. It should be recognized that these periods of demand for forest residues will be temporary, and although they may last several years, they will come to an end, perhaps abruptly.

The use of wood residues to produce chemicals, (including alcohol for fuel), has received a considerable amount of attention, but we should consider the total volume involved before speculating on the possible effect on forest residues. The total volumes for all the chemical extractives is very small when compared to the volumes of residue available, so that we can be sure that no matter what happens with extractives, the effect on forest residues will be negligible. Only the production of wood alcohol for fuel has a promise of significant volume, but there are technical and economic problems that are not yet resolved, so that it is too early to speculate on the prospects. The only thing we can be sure of is that it will not come soon.

POST, POLES, AND HOUSE LOGS

These three products have been combined, as all of them require sound wood in round wood form. All may be made of dead material, and posts can be either dead or can be small green trees.

The demand for posts and poles has been fairly steady over the past decade, and there seems to be no reason to expect any dramatic changes. The demand for posts may get a small boost from higher energy costs, as the cost of producing and transporting steel posts will go up more than will the costs for wood posts. This effect may be very important to an individual producer, but won't have a large effect on the total use of forest residues for these products.

Trends in the demand for house logs are very difficult to predict. Interest in log houses grew dramatically during the past five years, to the point that some producers were having difficulty in finding enough suitable logs. However, with the recent drop in housing, the log house market tumbled like everything else. It would appear that log houses follow about the same patterns as conventional housing, but may have more severe swings. Many of the log homes are used for vacation homes, where the demand may be very high in good times, and almost nil in bad times.

The house log industry has the potential for using significant quantities of the standing dead residues. With a steady source of material supply and efficient production techniques, log construction can compete economically with conventional housing construction.

FUEL

Energy production represents the greatest potential market for forest residues in this area, and although it is not currently feasable to use forest residues for fuel, we can expect that it will be in the near future. The process of converting to wood fuels is already well underway. Many of the larger forest related industries have already made the necessary changes to convert from natural gas or oil to wood. All of the current use of wood in this area, however, is based on mill residues (hog fuel) which are available for little more than the cost of transportation. We can expect a continuation of this trend until the available mill residues are all being used, which will not be long. At that time, there will not be a shift to forest residues relative to mill residues.

Instead, the process of conversion to wood will end, until rising prices for fossil fuels push the cost of energy high enough to make forest residues attractive.

In order to predict when forest residues will become economical fuel, one must forecast the price rise of fossil fuels relative to other costs. I have not seen anyone willing to attempt it. We should expect, though, that it will not happen within the next five years, but is quite likely within the next ten to twenty. It has already happened in the Northeast, where energy costs are much higher than they are here, and the costs of collecting forest residues are lower. There is at least one public utility, and several large industrial plants that are currently using forest residues to supply all of their energy.

To summarize, the four major potential uses for forest residues, none offer any immediate prospects for large scale use. We can expect cyclical demand for residues to supplement the material supply to the pulp and paper industry. These periods will occur when the demand for paper products remain high while the demand for lumber and plywood are down. We are now entering such a period, and may soon see an increased use for chipped forest residues. Posts and poles represent a fairly small but steady demand for standing dead residues, and a recovery at the housing market should revive the demand for house logs.

The rising cost of energy could generate the greatest potential demand for residues. Although forest residue is not currently an economical fuel in this area, we should expect that it will become so in the near future.

RESIDUE UTILIZATION AND THE REGIONAL ECONOMY

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ABSTRACT

The wood products industry is vitally important to the economy of western Montana. Forty to forty-five percent of the earnings in western Montana's basic or export industries comes from the wood products and paper industries. Whether or not forest industries in the Rocky Mountain region hold their own, decline, or expand in future years depends mostly upon the area's ability to compete in the national market, and upon the availability of raw materials. Increased residue use may prove to be Montana's only chance of maintaining the forest industry at or near its present level of activity.

KEYWORDS: residue utilization, timber availability, Montana

During this symposium we have discussed a topic of great importance to the forest industries and to the Rocky Mountain states: better utilization of raw material resources through the harvesting and use of forest residues. Residues are important to the industry because it needs the raw materials and important to the region because it needs the jobs and income the industry provides. In this paper, I will discuss the significant role of the forest products industry in western Montana, its prospects for the future, and the importance of these discussions to that future. My hope is that these comments will provide an economic perspective for the papers presented previously.

Perhaps no part of the Rocky Mountain region is more dependent upon the forest industries than western Montana. The private forest products sector alone has provided from 40 to 45 percent of the economic base of this area in recent years. By that I mean that 40 to 45 percent of the earnings in western Montana's basic or export industries comes from the wood products and paper industries. Earnings include both wages and salaries and proprietors' income. If the salaries of federal and state employees in forest industry-related jobs were added to industry earnings, the combined figures would approach or exceed 50 percent of total earnings in the area's basic industries.

Those of you who have not been in western Montana or Missoula recently will have noticed some changes. The growth that has occurred here in the past few years -- the substantial number of new employment opportunities which has been created -- is largely attributable to the forest industries. Their growth has made possible much of the expansion in retail trade, services, and other consumer-oriented businesses. We needed those jobs, as large numbers of young people entered the labor force and as more women sought employment.

Yet industry spokesmen and economists interested in the forest products industry have for some time been concerned about its long-run prospects in western Montana. There still is a real question as to whether the industry can maintain its relative contribution to the area economy during the next twenty years.

The events of the past decade in western Montana will help put the present situation in perspective. They are not so different, I suspect, from what has happened in other parts of the Rocky Mountain area. Certainly the early 1970s were not an auspicious time for the industry. After a rapid expansion in the sixties, it was clear that times were changing. There was no longer any doubt that the supply of federal timber available to the industry would decline. Despite a booming U.S. housing market, lumber and plywood production in this area just held its own between 1970 and 1973. Total industry employment and earnings showed little change. Then in late 1974 and 1975, the national recession hit the forest industry. Employment and earnings fell off sharply. The year 1975 was a dismal one for the industry and for western Montana.

And then a funny thing happened, just when some people assumed the industry was on its way to a permanent plateau or a downhill slide: its recovery from the recession turned into a period of rapid expansion. Total 1978 earnings of workers in the forest industries were up about 44 percent from 1975, after adjustment for inflation, while employment was growing by 32 percent. As a result of the rapid post-recession growth, forest industry employment in 1978 exceeded 1969 levels for the first time in this decade by about 1,800 workers, and that's a substantial number in this part of the world.

Raw materials for the expansion have been provided by a large increase in the timber harvest from private lands, both industrial and nonindustrial, beginning about 1974. According to forest service estimates, the total cut on private lands increased by almost one-half -- 46 percent -- between 1973 and 1978. Going back again to 1969 for comparison puts the situation in perspective: the 1978 harvest from private lands is estimated to have been 73 percent higher than the 1969 harvest, while the cut from federal, state, and Indian lands was down 42 percent. Without the increase in private harvest, total timber cut in Montana in 1978 would have been 30 percent below 1969, and western Montana would have been quite a different place from what it is today. Traffic congestion in Missoula would have been less of a problem, but the lines at the unemployment office would have been considerably longer.

While a substantial shift has been taking place in the timber harvest during the past decade, significant changes also have occurred in the structure of the industry. Employment estimates leave a lot to be desired, especially the industry breakdowns. But they do provide a tentative measure of changes in structure, and in the economic contribution of various segments of the industry.

Sawmills, plywood, and millwork plants, together with logging operations, continue to employ the great bulk of industry workers in Montana. Their proportion of the total, however, has declined from around 93 percent during the early seventies to from 86 to 89 percent in the past few years. Within this group, plywood has assumed greater importance. Employment in plywood plants has doubled since 1969, with more than 1,000 new workers. The numbers of logging and sawmill workers appears to be slightly smaller, and the number of sawmills has declined significantly.

The other segments of the industry -- mostly plants producing pulp and paper, particleboard, and fiberboard -- have added several hundred new jobs since 1969. These plants' share of total employment -- which recently has varied from 11 to 14 percent -- should increase a bit more when a Missoula paper mill expansion is completed next year. The growth of these industries is significant, of course, because they use mill or forest residues. With the pulp and paper mill expansion, we may see the first large scale use of logging residues in western Montana.

So as the 1970s end, despite all the problems of the past decade, the forest products industry in Montana is more diversified and is employing more people than it did ten years ago. But, what about coming decades?

We all know that the short run outlook for the industry is not good. We already are seeing short work weeks and layoffs in response to a falling U.S. housing market. But we are more concerned with the longer term prospects in our discussions today. Whether or not forest industries here in western Montana, and in the Rocky Mountain region, hold their own, or decline, or even expand, in future years, depends mostly upon the area's ability to compete in the national market, and upon the availability of raw materials.

Large numbers of young people from the high birth rate years of the fifties and sixties will reach the home buying age during the next decade. There is not much doubt that a strong national demand for new housing will exist during the 1980s, if construction funds are available. This means that the demand for lumber, plywood, and board products also should be strong; how strong depends upon the relative price of wood compared to other building products.

The demand for Rocky Mountain wood products may well hinge upon what happens in other parts of the country. Will the Rocky Mountain region be able to hold its share of the national market? We don't know. Certainly not if adequate timber resources are not available.

Will adequate raw materials be available to the industry in Montana? There is general agreement, I think, that the high level of harvest on private lands, which made possible the expansion during the late seventies, cannot be maintained during the eighties and beyond. Users of private timber will be gradually forced to look to public lands for a larger share of their raw materials. Given present legislation and national policy, apparent public opinion, and probable funding levels for public land management agencies, it seems to me unrealistic to expect any significant increase in public timber harvest in the 1980s.

Paul Polzin, an economist in our Bureau, has prepared some projections of the demand for softwood sawtimber from Montana forests to the year 2000 and beyond. One set of these projections assumes that prices for wood building products continue to rise faster than prices of competing building

materials (a reasonable expectation) and that Montana holds its 1970 share of the national market. His estimates indicate that under these conditions we would need to harvest timber at about the same rate in both the 1980s and 1990s as we did in 1978. That probably will not happen. Before the year 2000 rolls around, our supply of timber may fall short. It may not be a severe shortfall, but it likely will be enough to cause some severe problems for individual mills.

To assume that Montana can hold its share of the national building material market may be unrealistic; certainly some economists think so. But from the standpoint of the economic welfare of western Montana, it is a goal worth shooting for.

The fact that it is quite possible that over the next twenty years there will not be enough timber to hold our share of the market gives greater urgency to the topics discussed in these papers. An area heavily dependent upon a single industry with an uncertain source of materials, an area with a growing labor force, and few prospects for expansion of its economic base through growth in other activities, has a right to be concerned about its future. So, of course, does the industry.

Certainly the industry should continue to press for as much public timber as good land management will permit. Realistically, however, increased use of forest residues may prove to be Montana's only chance of maintaining the forest industry at or near its present level of activity. Increasing residue use may be a long, slow process; it will require further structural changes within the industry. If the forest industry employs 10,000 or 12,000 people in Montana in 1995, it will be a different industry from the one we know today.

As a Montanan and an economist, I am pleased to have participated in this discussion of the prospects for utilizing forest residue in the Rocky Mountain region. I hope that decision makers in both the private and public sectors will continue to look at options for using these materials, and for restructuring the forest industry in a way that will permit it to continue in its important role as a source of employment and income.

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USDA Forest Service.
1981. Harvesting and utilization opportunities for forest residues in the Northern Rocky Mountains. USDA For. Serv. Gen. Tech. Rep. INT-110, 294 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

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KEYWORDS: timber harvesting, timber processing, utilization, forest residues

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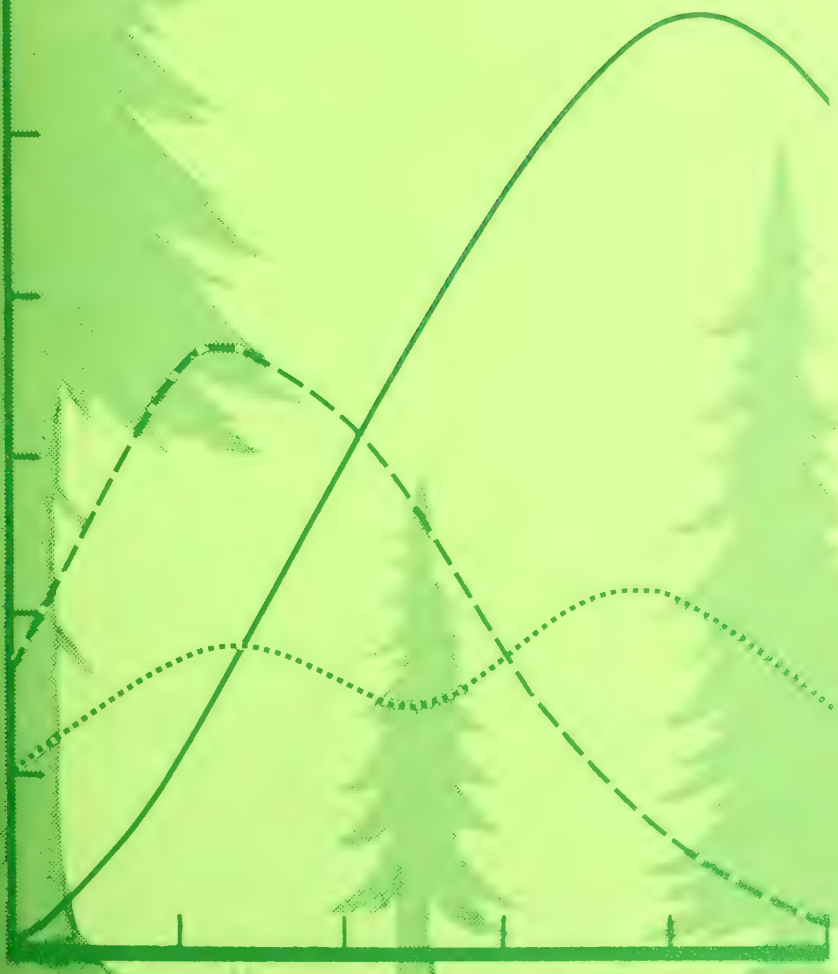
**Intermountain
Forest and Range
Experiment Station**

General Technical
Report INT-111

April 1981

Modeling Seasonal Abundance of Douglas-Fir Beetle in Relation to Entomophagous Insects and Location in Trees

Michael A. Marsden, Malcolm M. Furniss,
and LeRoy N. Kline



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RESEARCH SUMMARY

Distributions of Douglas-fir beetles and entomophagous insects were sampled weekly at 3 m intervals on stems of trees. Regression models were developed for predicting abundance of Douglas-fir beetles in relation to entomophagous species, date, and sample characteristics. The logistic function was used to define the probability of the presence of entomophagous insects on samples. An average of 58 percent mortality of Douglas-fir beetle progeny was attributed to entomophagous insects. Suggestions are given on locations of samples and number of samples needed for a given precision of estimate for Douglas-fir beetle and entomophagous species.

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INTRODUCTION

Infestations of the Douglas-fir beetle *Dendroctonus pseudotsugae* Hopk. cause great economic losses of its principal host, *Pseudotsuga menziesii* [Mirb.] Franco (Furniss and Orr 1978). Mature trees are commonly killed after predisposing factors such as windstorms and droughts enable the beetle population to increase.

The Douglas-fir beetle develops through its four life stages (fig. 1) hidden under the bark of its host tree. Most beetles overwinter as callow adults, then fly and infest other Douglas-fir trees during spring. The females bore into the bark and excavate unbranched egg galleries upward in the phloem for an average distance of 15 to 20 cm. The density of egg galleries ranges from 5 to 12 per 0.1 m^2 in standing trees. Eggs are laid alternatively on opposite sides of the gallery at a rate of 3.1 per cm in Idaho. Eggs hatch in a week or two. The larvae then mine fanlike (fig. 2) from the egg gallery. Larvae complete their mines in a month or so, then construct cells in which they transform to pupae for a brief time before becoming adults. Death of the tree results from a combination of girdling by larvae and the action of microorganisms associated with the beetle.

Distribution of beetles and entomophagous insects in trees was investigated in central Idaho (Kline 1963) as a part of a long-term study of population dynamics by Furniss. That thesis presented graphically the abundance of these organisms by sampling height and date. In this paper, we utilize regression analyses and the logistic function to relate quantitatively the Douglas-fir beetle population density to the number of predators and parasites in relation to time and location in trees. The improved methods provide a means of expressing relationships that previously were either not recognized or incapable of definition. This information will facilitate the evaluation of Douglas-fir beetle infestations for such purposes as predicting trend of population and damage, relating Douglas-fir beetle populations to factors affecting tree susceptibility; and will aid in developing improved sampling procedures.

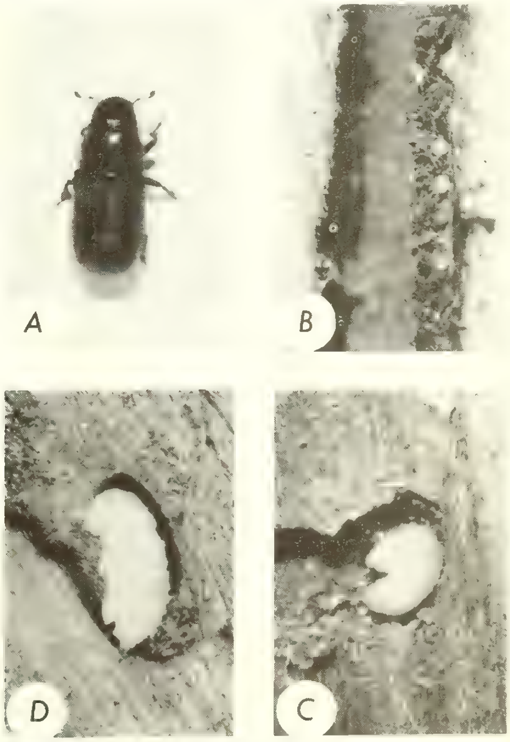

Figure 1.--Douglas-fir beetle life stages. (A) adult; (B) eggs in gallery; (C) larva; (D) pupa.

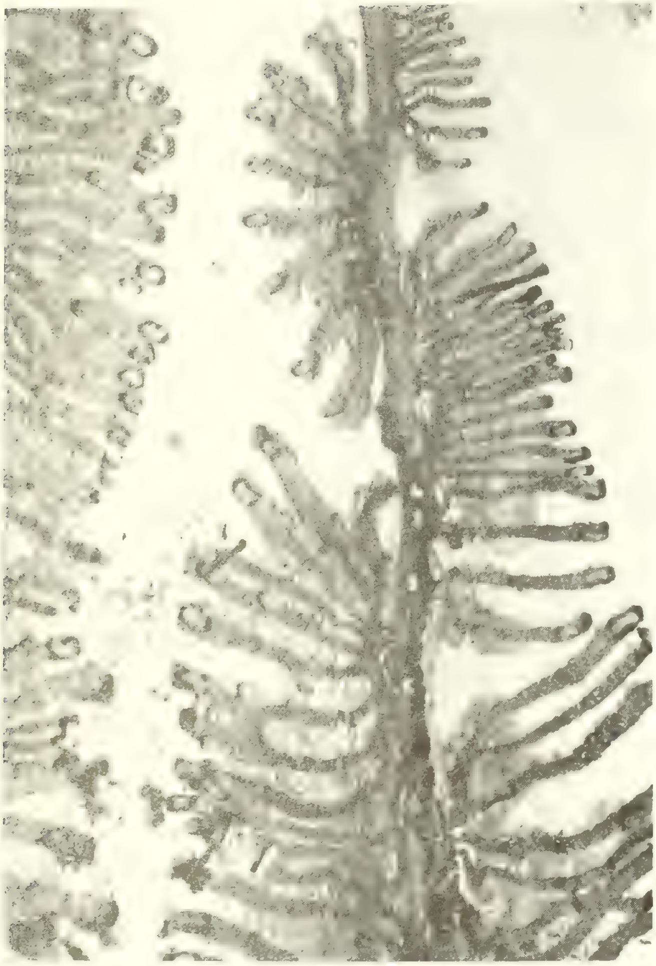

Figure 2.--Douglas-fir beetle egg gallery and larval mines.

Figure 3.--Comparison of samples. Circular sample was used to measure Douglas-fir beetle galleries and progeny; rectangular sample was used to count entomophagous insects on adjacent area.

METHODS

The study was scheduled to begin when sufficient time had elapsed after beetle attack to reveal trees that were going to die. We thereby eliminated tree resistance as a source of mortality to beetle progeny, and galleries were nearly completed, which resulted in less variation in weekly measurements.

Five infested trees were felled weekly for sampling beginning June 30, 1960. Sampling ended September 2. Samples (fig. 3) were taken at 3 m intervals, beginning 1.5 m above ground to a diameter of 20 cm. Numbers of entomophagous insects were measured on a 15 cm x 30 cm sample, but because Douglas-fir beetle galleries, ventilation holes, and progeny were more abundant, they were measured on an adjacent 93 cm^2 circular sample cut with a bark punch (Furniss 1962a). Other data obtained at each sample location were: diameter of trunk, bark thickness, and height of sample.

Analyses

We used actual sample values rather than converting data to a common area basis. Thus, all counts of entomophagous insects are on a 15 cm x 30 cm (0.45 m^2) basis whereas densities of Douglas-fir beetle progeny and length of egg galleries are on a 93 cm^2 basis.

To estimate rates of survival of Douglas-fir beetles from predation and parasitism, we used ratios of numbers of Douglas-fir beetle progeny to the total length of egg galleries. Initial beetle population (eggs) is related to egg gallery length (Furniss 1957), there being an average of 3.1 eggs/cm.

Simple linear regression was used to relate Douglas-fir beetle population indices to entomophagous insects. To determine the variation explained by regression models, we calculated multiple regression coefficients (R^2).

The following list of variables was considered a basic set for the presence or absence of entomophagous insects: date, height, length of egg galleries, maximum bark thickness, diameter, and number of ventilation holes. Transformations of those variables were also tested in the model building.

In developing the model, the response was fitted to the entire list of variables first. Coefficients in the model were tested for significance by Student's t-test. Variables with nonsignificant ($\alpha < 0.05$) coefficients were deleted and the coefficients for the remaining variables were recomputed.

The logistic function (Walker and Duncan 1967) was used to define the probability of the presence of entomophagous insects using Hamilton's (1974) program. The goodness of fit of the predicted and observed values was tested by chi-square analysis.

Relationships of dependent (e.g., number of Douglas-fir beetles) and independent (e.g., number of entomophagous insects) variables were portrayed with an HP9820 calculator/plotter. The same device was used to plot the logistic function relating entomophagous insects (*Coeloides* or *Medetera*) and sample characteristics.

The efficiency of sampling beetle progeny at 1.5 m and 4.6 m above ground was compared by the degree to which their means were correlated with tree means. Numbers of samples needed to estimate average gallery length, beetle progeny, or entomophagous insects were calculated for a 0.20 coefficient of variation of the mean ($CV_{\bar{x}}$) using the formula $n = (CV_{\bar{x}}/0.20)^2$. This is equivalent to setting sample size for a desired relative variance (Kish 1965).

BIONOMICS OF SPECIFIC PREDATORS AND PARASITES

The insect enemies of the Douglas-fir beetle found in this study are discussed in the general order of their density on samples.

COELOIDES VANCOUVERENSIS [Dalla Torre]

In thin bark portions of trees, *C. vancouverensis* (=*brunneri* Viereck) can be very effective in parasitizing a large percentage of the Douglas-fir brood (fig. 4B) (Ryan and Rudinsky 1962). For instance, Bedard (1933) reported an average of 29 percent of beetle larvae were parasitized, varying from 0-10 percent in the base to 70-95 percent in the top.

Females deposited eggs through the bark (fig. 4A) onto beetle larvae, beginning in early July. By the end of July the parasite was found frequently in trees. Due to a different rate of development, some parasite progeny overwinter as larvae. Others mature and emerge in August to lay eggs on other beetle larvae. The proportion of fast-developing adults may be 95 percent in western Oregon (Ryan and Rudinsky 1962) or a small minority in northeastern Washington (Bedard 1933). Each *C. vancouverensis* larva consumes only a single beetle larva, so the number of *C. vancouverensis* larvae (or their cocoons which are easily counted) equals the number of bark beetle larvae that have been parasitized.

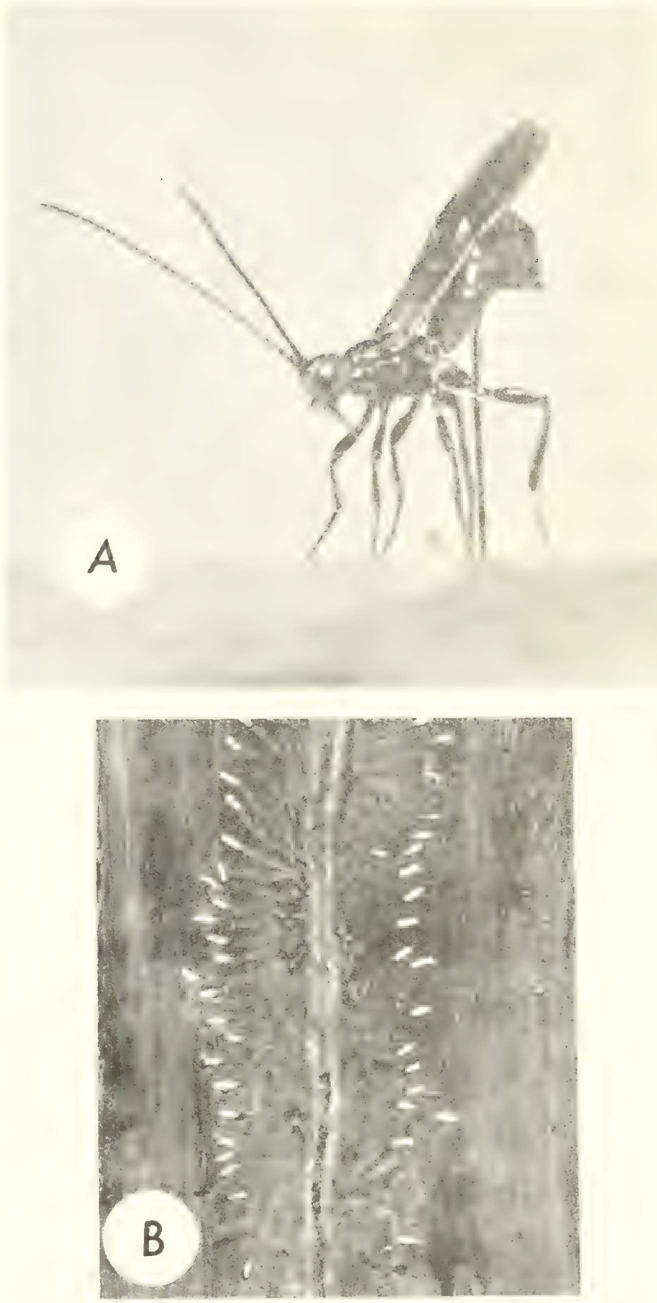

Figure 4.--*Coeloides vancouverensis* ovipositing (A) on beetle larva in bark, and cocoons (B) marking demise of beetle larvae.

MEDETERA SPP.

Both *Medetera aldrichii* Wheeler and *M. vidua* Wh. were present, but the latter was much less abundant. Adults (fig. 5A) began to appear in late May, becoming abundant in June. Eggs are laid on small groups of 1 to 3 in bark crevices (Bedard 1933). Larvae (fig. 5B) began to appear on samples June 30. The average number of Douglas-fir beetle larvae killed per *Medetera* larva is unknown.

A

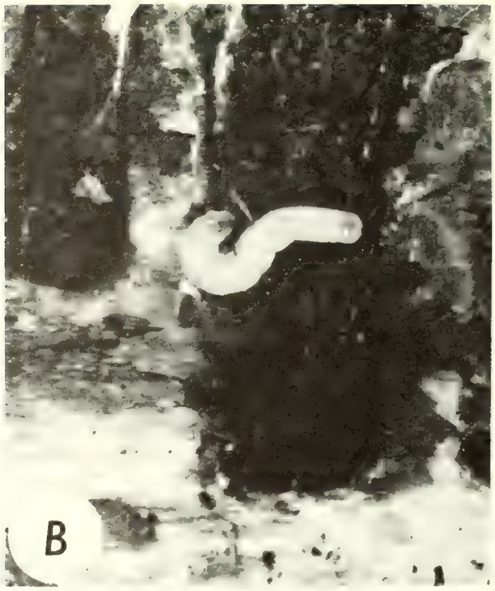

Figure 5.--*Medetera* adult (A) and larva (B).

ENOCLERUS SPHEGEUS Fab.

Enoclerus sphegeus Fab. adults (fig. 6A) emerged in May and preyed on attacking adult Douglas-fir beetles. Eggs are laid in clusters under scales of the outer bark (Kline and Rudinsky 1964). The newly hatched larvae apparently enter the beetle galleries through holes made by the bark beetles, after which they feed on immature stages of *D. pseudotsugae.*

Larvae of E. sphegeus (fig. 6B) were present on samples throughout the sampling period (fig. 7) although they diminished in abundance after mid-July when most larvae migrated to the root crown where they formed pupal cells in the outer bark or duff. In laboratory tests, larvae ate an average of 0.5 *D. pseudotsugae* larva per day (Bedard 1933) and 15 to 38 *Dendroctonus ponderosae* Hopk larvae, depending on prey size (Amman 1970). Such high mortality rates seem unlikely in nature due to the somewhat dispersed and isolated nature of prey larvae.

A

B

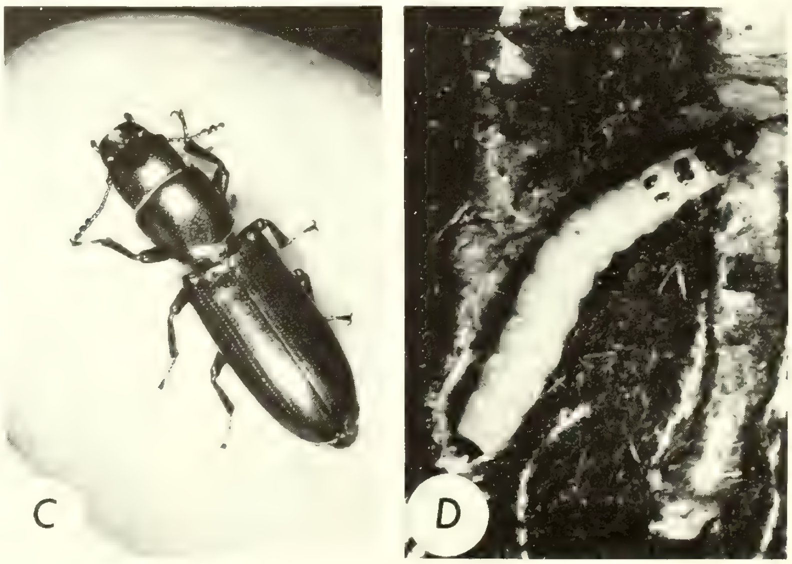

Figure 6.--Two predators of similar habit: *Enoclerus sphegeus* adult (A) and larva (B); and *Temnochila chlorodia* adult (C) and larva (D) searching for prey.

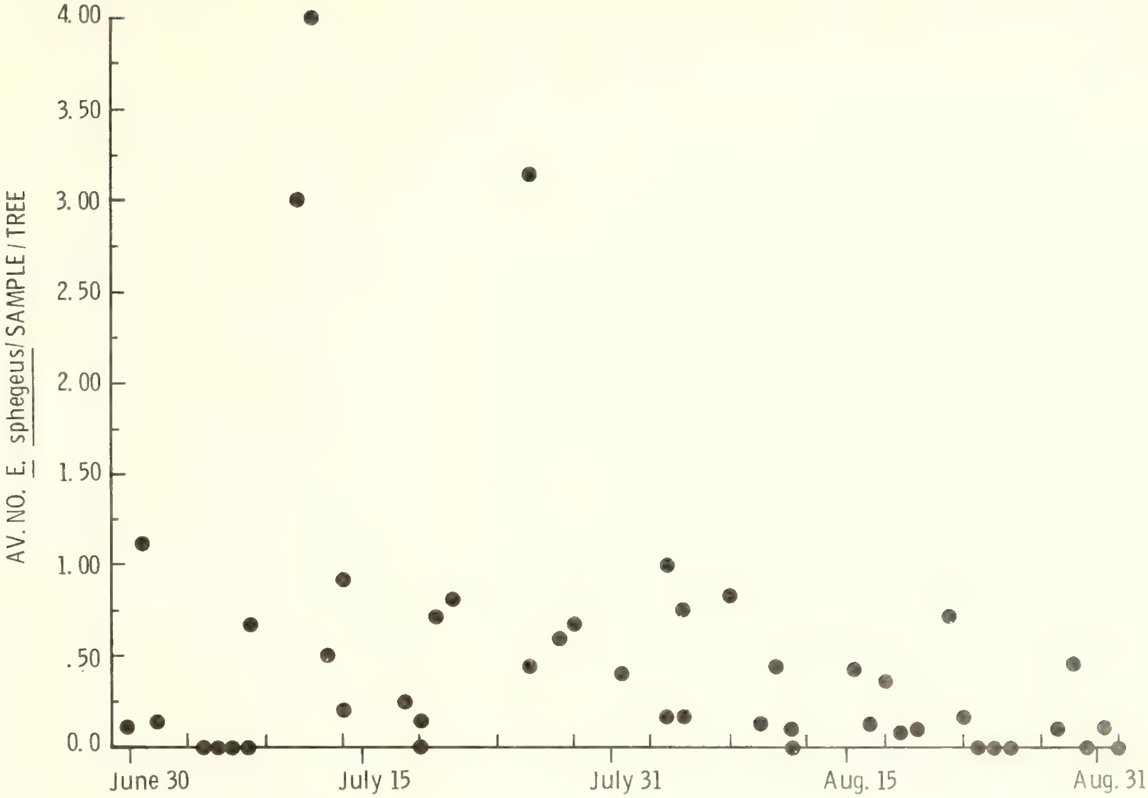

Figure 7.--Average number of *Enoclerus sphegeus* per sample per tree by day of the year on which the tree sampled.

THANASIMUS UNDATULUS Say

Larvae of *Thanasimus undatulus* Say were present at low frequency (fig. 8). They may prefer smaller bark beetles such as *Pseudohylesinus nebulosus* (Lec.) or *Scolytus monticolae* (Sw.) (Schmitz 1978). The seasonal history is similar to that of *E. sphegeus* with the exception that the larvae do not migrate to the base of the tree.

TEMNOCHILA CHLORODIA [Mann.]

T. chlorodia larvae (fig. 6D) were found throughout the summer in abundance similar to the clerids (fig.9). More recent work indicates that this metallic green or blue predator (fig. 6C) is much less abundant in northern Idaho (Furniss and others 1979). It also seems less important in Douglas-fir of western Oregon (Kline and Rudinsky 1964). The seasonal history of *T. chlorodia* follows that of *E. sphegeus* except that the larvae do not migrate.

ROPTROCERUS ECCOPTOGASTERI Ratz, *CECIDOSTIBA BURKEI* Crawford, and *CECIDOSTIBA DENDROCTONI* Ashmead

These pteromalids are grouped together because the larvae (fig. 10) are similar in appearance and habit. They may be more important as parasites of *Pseudohylesinus nebulosus* [Lec.] and *Scolytus monticolae* [Sw.] in tops of trees killed by *D. pseudotsugae.* These parasites were most abundant in the late summer (fig. 11).

BELOSTA ALBIPILOSA Hardy

The scenopinid fly, *B. albipilosa* [Hardy] (fig. 12) was discovered in this study for the first time preying on Douglas-fir beetle progeny beneath bark (Kelsey 1969, p. 275). The segmented white larvae are elongate and possess a beak-like extension of the head (fig. 12). They were recorded on samples only in late summer (fig. 13).

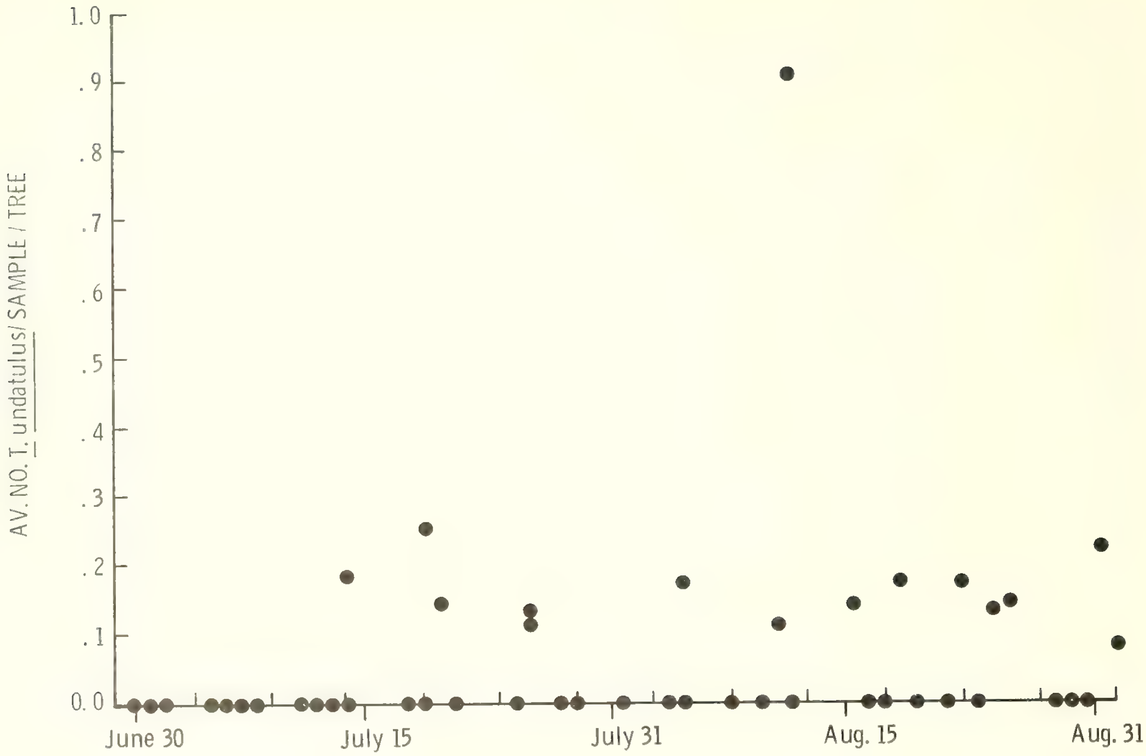

Figure 8.--Average number of *Thanasimus undatulus* per sample per tree by day of the year on which the tree was sampled.

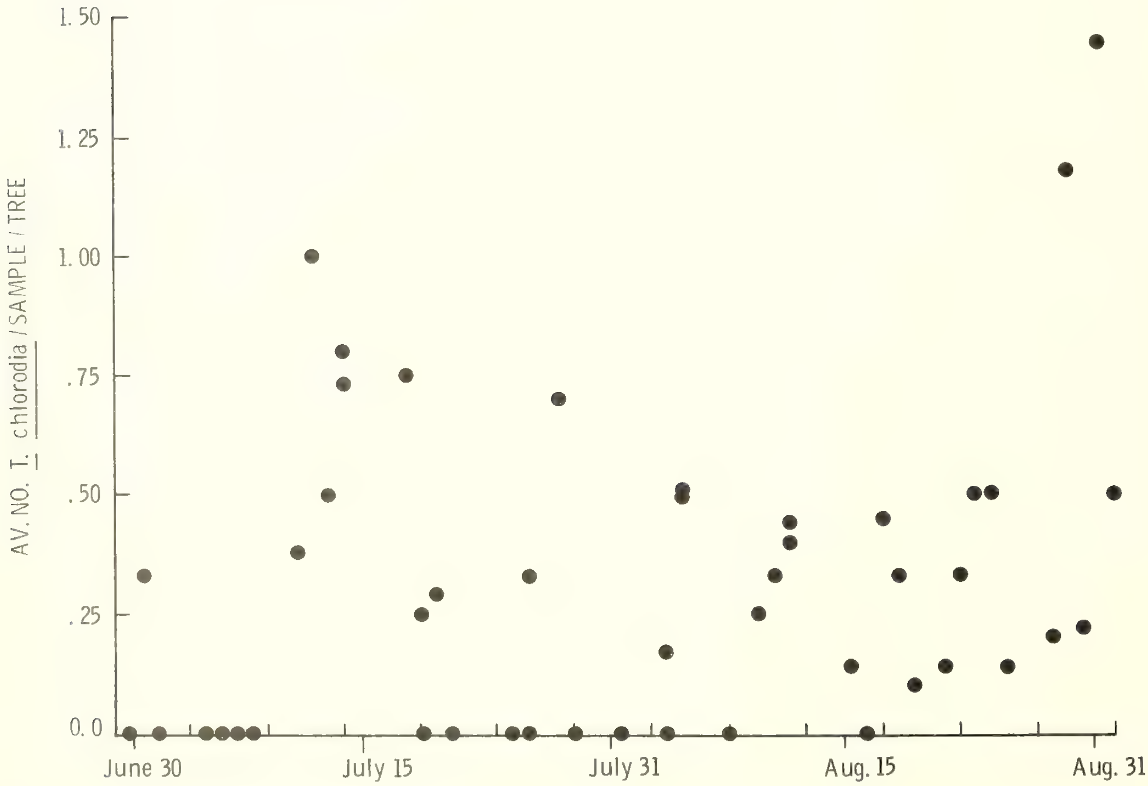

Figure 9.--Average number of *Temnochila chlorodia* per sample per tree by day of the year on which the tree was sampled.

Figure 10.--*Roptrocerus* larva recognizable by crescent shape and absence of cocoon.

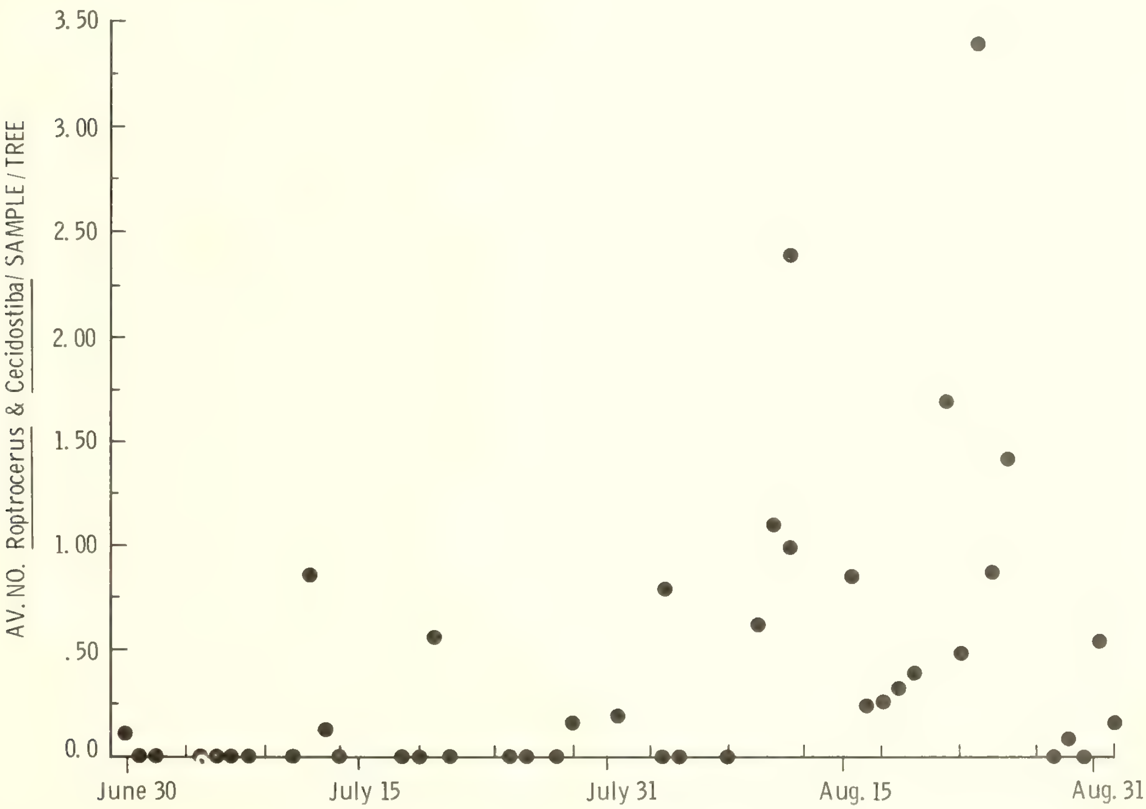

Figure 11.--Average number of *Roptrocerus* and *Cecidostiba* per sample per tree by day of the year on which the tree was sampled.

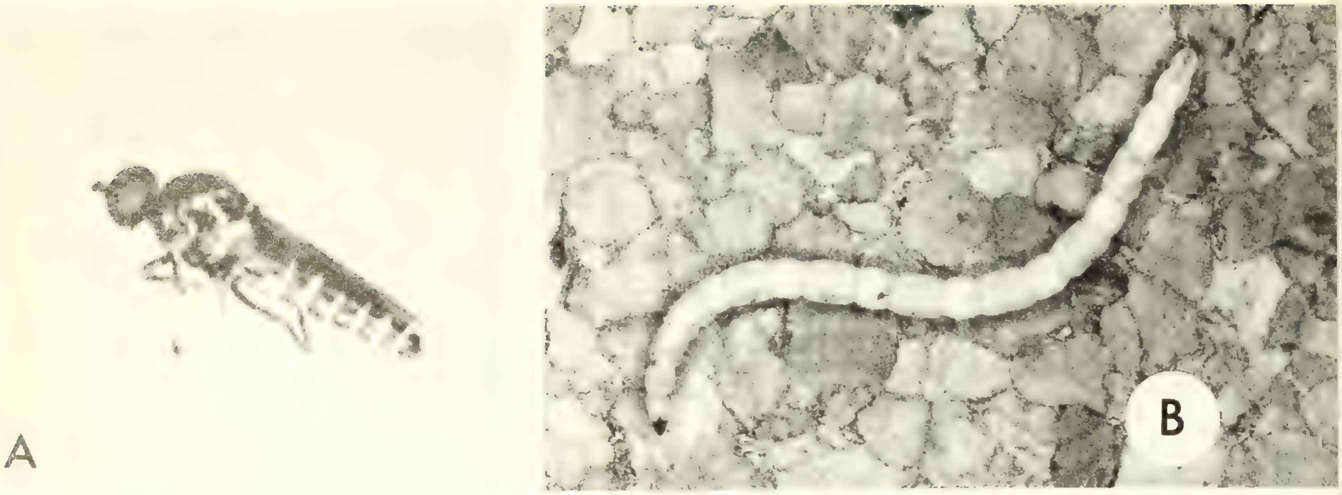

Figure 12.--*Belosta albipilosa* adult (A) and larva (B). The snakelike larva was discovered as a predator of Douglas-fir beetle during this study.

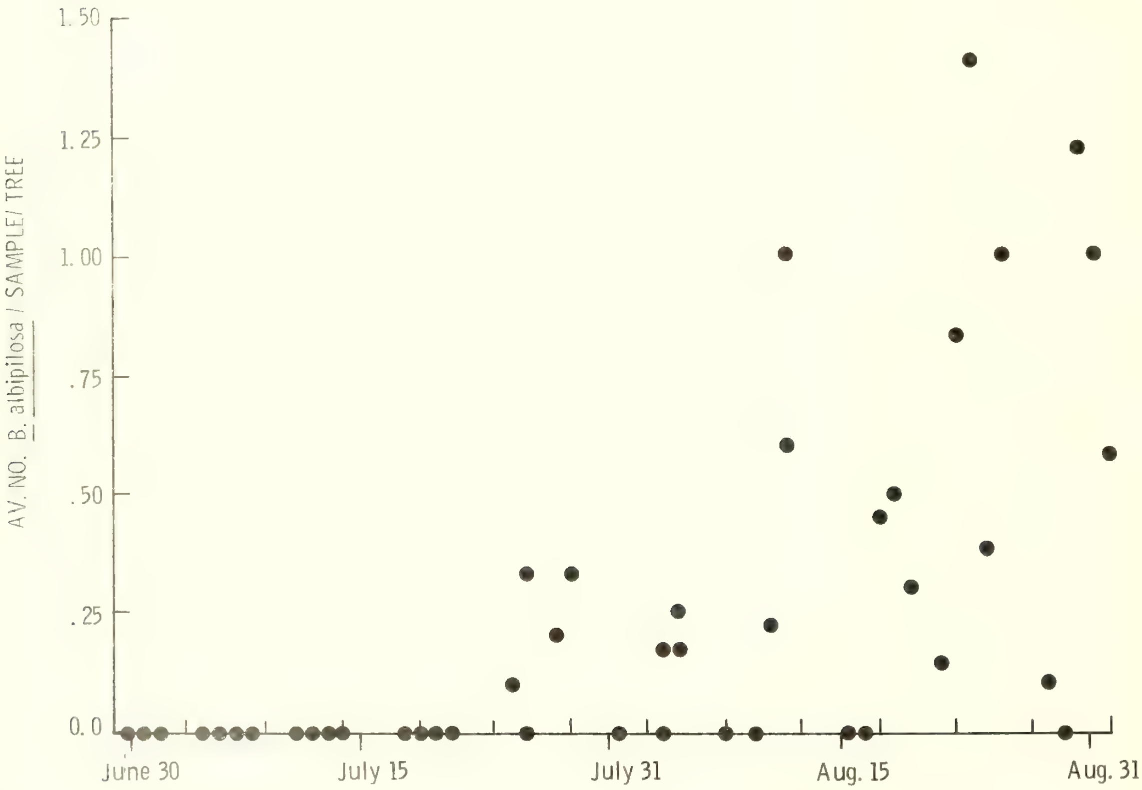

Figure 13.--Average number of *Belosta albipilosa* per sample per tree by day of the year on which the tree was sampled.

RESULTS AND DISCUSSION

After June 20, the length of egg galleries per tree did not increase. Therefore, if it were not for mortality factors the beetle population would have remained constant through the summer; however, density of beetle progeny per sample declined (fig. 14).

We hypothesize that the principal cause of reduction in beetle numbers in a **successfully** infested tree was due to entomophagous insects, not tree resistance or competition among progeny. This premise is supported by the following facts. We sampled only successfully attacked trees, that is, those low in resistance. Mortality from predation and parasitism acted to thin out progeny, lessening competition. The presence of the braconid wasp, *Coeloides vancouverensis* [Dalla Torre] (= *brunneri* Vier.) coincided with a sudden reduction in the beetle population. The average number of Douglas-fir beetle progeny was 4.72 per decimenter of egg gallery per tree. For sample trees with low numbers of entomophagous insects the average number of beetle progeny was 11.26 per dm of egg gallery. The ratio was 32.48 for the only tree lacking entomophagous insects when sampled.

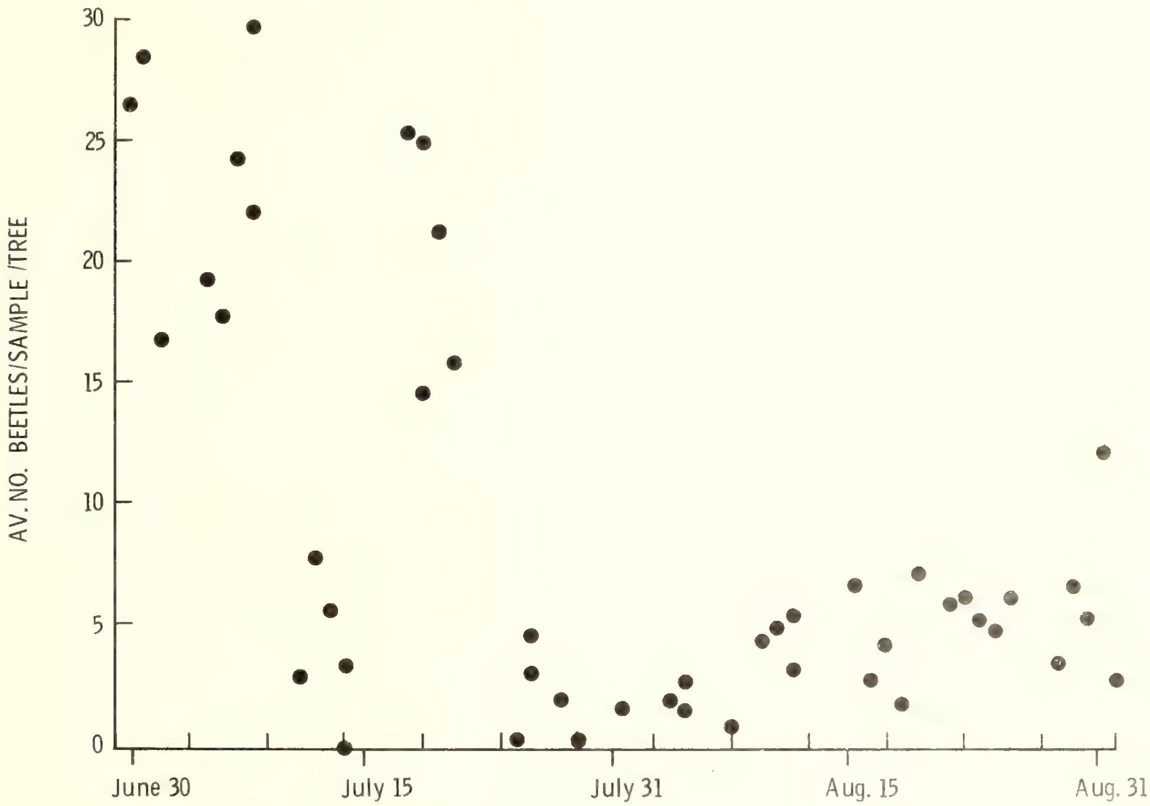

Figure 14.--Average number of Douglas-fir beetles per sample per tree by day of the year on which the tree was sampled.

Although the length of egg galleries did not increase on samples through the summer, it varied greatly from tree to tree. To remove most of this variation, we plotted over time the number of beetles per average length of egg gallery (fig. 15).

As expected, the number of Douglas-fir beetle progeny were inversely related to numbers of entomophagous insects (fig. 16). Density of beetle progeny at low numbers of any observed enemies was 11.26/dm of egg gallery but only 2.76/dm (76 percent fewer) at high frequency of parasites and predators. Progeny averaged 4.72/dm (58 percent fewer).

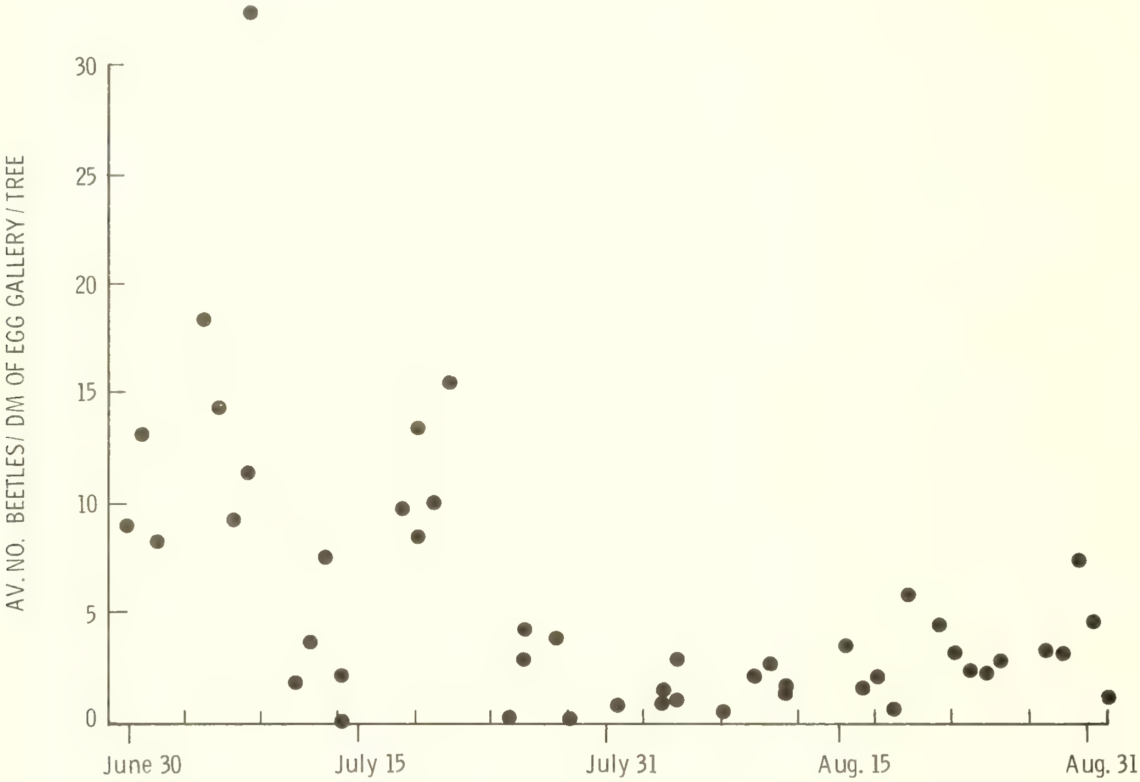

Figure 15.--Average number of Douglas-fir beetles per dm of egg gallery per tree by day of the year on which the tree was sampled.

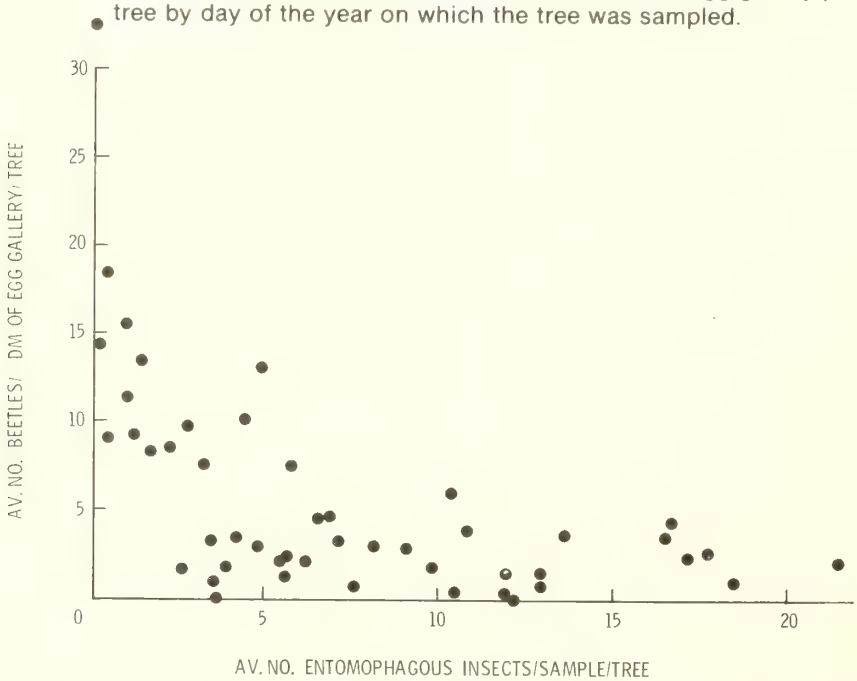

Figure 16.--Average number of Douglas-fir beetles per dm of egg gallery per tree vs. average number of entomophagous insects per sample per tree.

Population Models

DOUGLAS-FIR BEETLES

As a beginning point we used simple linear regression analysis to answer the question: Is the length of egg gallery per sample a function of tree diameter, sample height, and maximum bark thickness?

Five trees were selected at random from each of five diameter breast height classes (table 1). A quadratic effect of maximum bark thickness is suggested by these data, the average length of egg galleries being greatest at a maximum bark thickness of 1.27 to 1.78 cm. A quadratic form is also used for the sample height in the regression model:

$$Y_i = b_0 + b_1 x_{1_i} + b_2 x_{2_i} + b_3 x_{2_i}^2 + b_4 x_{3_i} + b_5 x_{3_i}^2 + e_i$$

where:

Y_i = length of egg gallery in the *i*th sample,

x_{1_i} = diameter at 1.5 m of tree from which *i*th sample is taken,

x_{2_i} = maximum bark thickness for the *i*th sample,

x_{3_i} = height at which *i*th sample occurred on the tree,

e_i = error associated with *i*th sample,

This regression model was then fitted to the total data set.

The regression model accounted for only a small percentage of the variation in the average length of egg galleries as indicated by the multiple correlation coefficient, $R^2 = 0.111$. The regression coefficient/significance levels were:

b_0 = 6.685/0.001

b_1 = -0.1109/.015

b_2 = -1.192/0.485

b_3 = 0.2691/0.627

b_4 = 0.0818/.054

b_5 = 0.008/.047

The significant coefficients in the model, i.e., those statistically different from zero, are tree diameter and sample height. The coefficients for maximum bark thickness were not different from zero.

Thus, for sampling length of egg galleries (which are proportional to initial beetle population), we conclude that tree diameter and sample height, not bark thickness, need be considered. As we discuss later, however, mortality factors such as *C. vancouverensis* are affected by bark thickness.

In sampling Douglas-fir beetles it is less costly to take samples from the more accessible lower part of standing trees. Would this result in a biased estimate of the density of bark beetles? In table 2 the density at 1.5 m is about one-half the average tree density. The density at 4.6 m is very close to the average density of egg galleries, and the simple correlation of the 4.6 m sample with the tree average is $R_{yx} = 0.640$, ($R_{yx}^2 = 0.410$). Therefore, average Douglas-fir beetle attack density per tree is estimated better at the 4.6 m height (a slightly lower height may suffice [Furniss 1962b]).

In order to relate 4.6 m samples to the tree as a whole, however, one needs a regression estimator (Kish 1965). From a regression of the average beetle density per tree on the density at the 4.6 m level, the following relationship was obtained:

$$Y_i = 0.750 + 0.580\ X_i,$$

where Y_i is average beetle density in the tree, X_i is the beetle density in the 4.6 m level sample.

Table 1.--Length of egg galleries (dm) and maximum bark thickness (cm) by sample height (m) for 5 sample trees in each of 5 diameter classes. The diameter (cm) for each tree at 1.5 m height is also presented

Sample height (m)	Average diameter (cm) at 1.5 m height				
	27.9	43.2	63.5	71.1	81.3
32.0					1.27(2.06)
29.0					1.02(0.48)
25.9					1.27(0.25)
22.9			1.02(2.46)	1.52(1.37)	1.78(3.53)
19.8			1.02(2.29)	1.27(2.34)	1.52(1.07)
16.8			1.02(2.79)	1.78(2.64)	1.78(0.81)
13.7		0.76(0.0)	1.52(2.34)	1.78(2.54)	2.29(2.01)
10.7		1.02(1.80)	1.27(2.41)	2.29(1.80)	2.03(3.00)
7.6	1.02(0.0)[1]	1.27(3.23)	2.03(1.45)	2.03(1.45)	2.29(1.32)
4.6	1.02(.91)	1.52(1.73)	1.78(1.68)	3.30(1.32)	2.54(1.32)
1.5	1.27(1.40)	2.79(0.0)	3.30(0.76)	5.08(0.0)	5.59(1.78)

[1]Maximum bark thickness (cm) and (length of egg galleries (dm))

Table 2.--Average and variance of length of Douglas-fir beetle egg galleries/sample per tree at the two lowest heights

Height	Length of galleries (dm)	Variance
1.5 m	0.81	0.68
4.6 m	1.60	.57
Average for tree	1.67	.46

Predators and Parasites

Sampling the Douglas-fir trees at the 4.6 m height may provide useful estimates of the density of bark beetles per tree, but what of predator and parasite densities?

Table 3 shows that for some predators and parasites (including the two most abundant) the 4.6 m sample is not a good estimate of the average density per tree. For *C. vancouverensis* the 4.6 m sample greatly underestimates the population (all-tree sample) density. For *Medetera* spp. the 4.6 m sample overestimates the all-tree sample by a large amount. *Roptrocerus* sp. and *Cecidostiba* sp. also have much larger densities per tree based on all samples than the density based on 4.6 m samples. However, these last two occur in very low frequency and are probably mainly parasites of other (secondary) bark beetles high in the tree.

Because *C. vancouverensis* and *Medetera* spp. were the most abundant parasite and predator, their distributions on the tree will be evaluated further.

Table 3.--Average number of predators and parasites per sample per tree and per sample at 4.6 m height

Species	Number per sample per tree	Number per sample at 4.6 m height
Enoclerus sphegeus	0.4973	0.5833
Thanasimus undatulus	.0699	.0416
Temnochila chlorodia	.3333	.4375
Coeloides vancouverensis	3.4919	1.7500
Roptrocerus sp. and *Cecidostiba* sp.	.4274	.2083
Medetera spp.	2.1693	3.5000
Total	7.4462	6.9375

COELOIDES VANCOUVERENSIS

Of the 372 samples taken, 80 contained *C. vancouverensis*. Of the 48 trees sampled, 21 contained *C. vancouverensis*. One hundred and twenty-three *C. vancouverensis* were found on samples in one tree and 50 occurred on one sample. This indicates a contagious distribution. We herein explore some reasons for this distribution.

Coeloides vancouverensis deposits eggs singly through the bark onto a 2nd, 3rd, or 4th instar *D. pseudotsugae* larva (Ryan and Rudinsky 1962). Larvae of this parasite were found beginning July 12, 12 days after start of sampling. The female is excluded from ovipositing in those areas of the tree where overlying bark is thicker than the 5 mm length of ther ovipositor. Density and distribution of host larvae, also govern the location and abundance of *C. vancouverensis*.

To model the distribution of *C. vancouverensis* at a sample location, a logistic function was chosen. The response variable (Y) was recorded as 1 if the parasite was present; 0 if the absent on a sample. The logistic function which defines the probability of the presence of a given insect is given by $Y = P(n > 0) = (1 + EXP[-BX])^{-1}$, where n is the number of *C. vancouverensis* (an integer greater than or equal to zero). EXP is the exponential function. X is a vector of independent variables (bark thickness, height, etc.). B is a vector of coefficients to be estimated.

Walker and Duncan (1967) developed an efficient method of estimation for the coefficient vector B. The algorithm has been packaged as a computer program in Fortran IV (Hamilton 1974). Using that procedure, the following model was derived for individual samples:

$$Y_j = (1 + EXP[f(X_j, B)]^{-1} + e_j$$

where

$$f(X_j, B) = B_0 + B_1 X_{1_j} \times B_2 X_2 + B_3 X_{3_j} + B_4 X_{4_j}$$

and e_j is the error associated with the jth sample.
The variables used have the following identification:

Y_j = the presence of *C. vancouverensis* (1 = present, 0 = absent),
X_{1_j} = date of the jth sample,
X_{2_j} = length of egg galleries (dm) in the jth sample,
X_{3_j} = maximum bark thickness (cm) of the jth sample,
X_{4_j} = number of ventilation holes in the jth sample,

The estimates of these coefficients based on this data set are:

b_0 = -13.6380 $\quad$ b_3 = -0.6450
b_1 = 0.0650 $\quad$ b_4 = 0.1680
b_2 = 0.1299

The degree of fit is seen in table 4. Here the observations are grouped into classes according to their predicted values. For example, Class 1 contains only one observation. Of the 372 samples, the model predicted a probability of 0.01 or less *C. vancouverensis* for only one sample. This sample did not contain *C. vancouverensis*. By contrast, Class 20 contains those samples for which the predicted probability of containing *C. vancouverensis* is 0.90 < 0.95. This class contains 10 samples of which 9 contain *C. vancouverensis*. The excellent agreement of expected and observed *C. vancouverensis* is indicated by a chi-square statistic of 0.01 for this class. An overall chi-square for the 21 classes is 13.60, which indicates good degree of fit for the logistic function.

Table 4.--Number of samples with *C. vancouverensis* as a function of the expected frequency and chi-square values for degree of agreement between the expected and observed frequencies

Class	Probability of presence of *C. vancouverensis*	Number of samples	Number of samples with *C. vancouverensis*	Expected number of samples with *C. vancouverensis*	Chi-square
1	0.0 - 0.01	1	0	0.0	0.01
2	.01 - .05	9	0	.3	.27
3	.05 - .10	23	0	1.7	1.73
4	.10 - .15	35	1	4.4	2.63
5	.15 - .20	33	4	5.8	.55
6	.20 - .25	27	6	6.1	00
7	.25 - .30	21	8	5.8	.87
8	30 - .35	19	11	6.2	3.83
9	.35 - .40	14	7	5.2	.59
10	.40 - .45	9	2	3.8	.88
11	.45 - .50	8	5	3.8	.38
12	.50 - .55	5	2	2.6	.15
13	.55 - .60	18	13	10.3	70
14	.60 - .65	15	11	9.4	.29
15	.65 - .70	20	14	13.5	.02
16	.70 - .75	18	12	13.0	.09
17	.75 - .80	30	21	23.2	.23
18	.80 - .85	34	29	28.0	.03
19	.85 - .90	18	14	15.7	.20
20	.90 - .95	10	9	9.2	.01
21	.95 - 1.00	5	4	4.9	.16
Total					13.60

Figure 17 shows the relationship of date and the probability of *C. vancouverensis* being present, if other variables in the model are held at their average values. This function reflects the rapid increase in frequency of *C. vancouverensis* during midsummer (fig. 18). The probability of presence of *C. vancouverensis* is also positively correlated with the average length of egg galleries (fig. 19). Bark thickness strongly affects the probability of occurrence of *C. vancouverensis* (fig. 20). Samples at 4.6 m height contain thicker bark than samples taken higher up the tree, and this explains why the 4.6 m sample under estimates the average density of *C. vancouverensis*.

MEDETERA SPP.

Medetera spp. were the most numerous predators in the trees and occurred over the entire sampling time period (fig. 21). They were found more frequently at the 4.6 m level than on the average of all samples from the tree. Greater moisture in thick bark portions of the tree probably protect the larvae from desiccation.

Again the logistic model can be employed to determine where the *Medetera* spp. are most likely to occur. The model is of the form:

$$Y_j = P(n_j > 0) = (1 + \mathrm{EXP}[X_j, B])^{-1} + e_j$$

where the function $f(X_j, B)$ will contain both linear and quadratic terms and e_j is the random error component.

The following variables were used in the model:

Y_j = the presence of *Medetera spp.* (1 = present, 0 = absent),

X_{1_j} = the date of the *i*th sample,

$X_{2_j} = X^2_{1_j}$,

X_{3_j} = the height (m) of the *i*th sample,

$X_{4_j} = X^2_{3_j}$,

X_{5_j} = the maximum bark thickness (cm) of the *i*th sample,

$X_{6_j} = X^2_{5_j}$,

X_{7_j} = the number of ventilation holes in the *i*th sample,

$X_{8_j} = X^2_{7_j}$,

X_{9_j} = the diameter (cm) of the tree at the height where the *j*th sample was taken.

The sample estimates of the coefficients for the above model are:

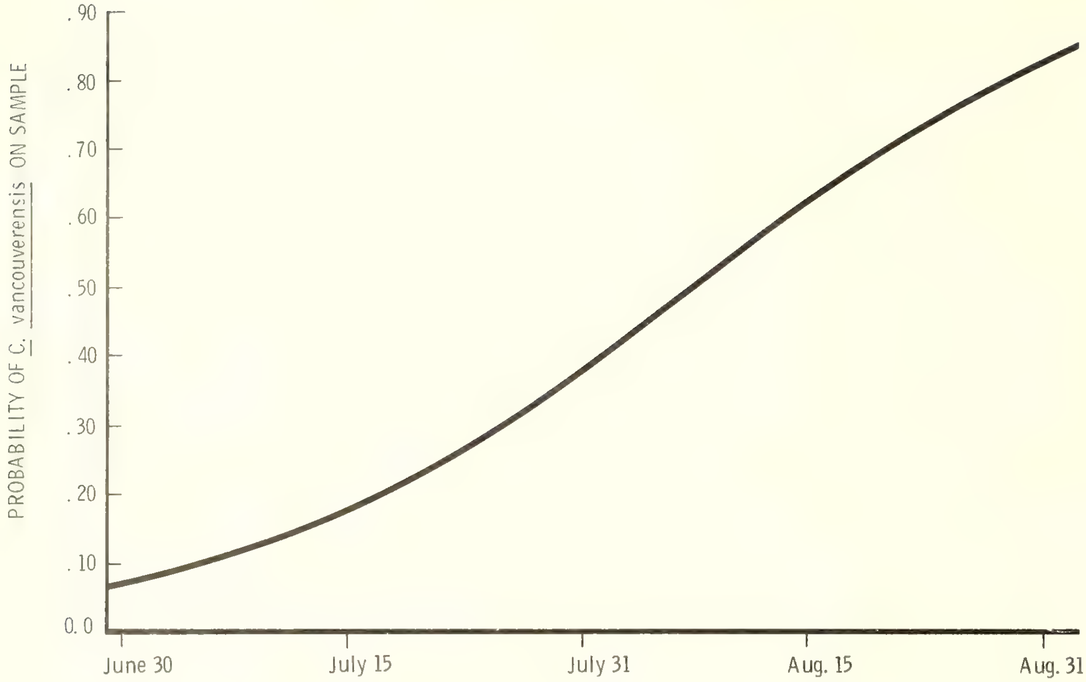

Figure 17.--Probability of *C. vancouverensis* on a sample as a function of day of the year.

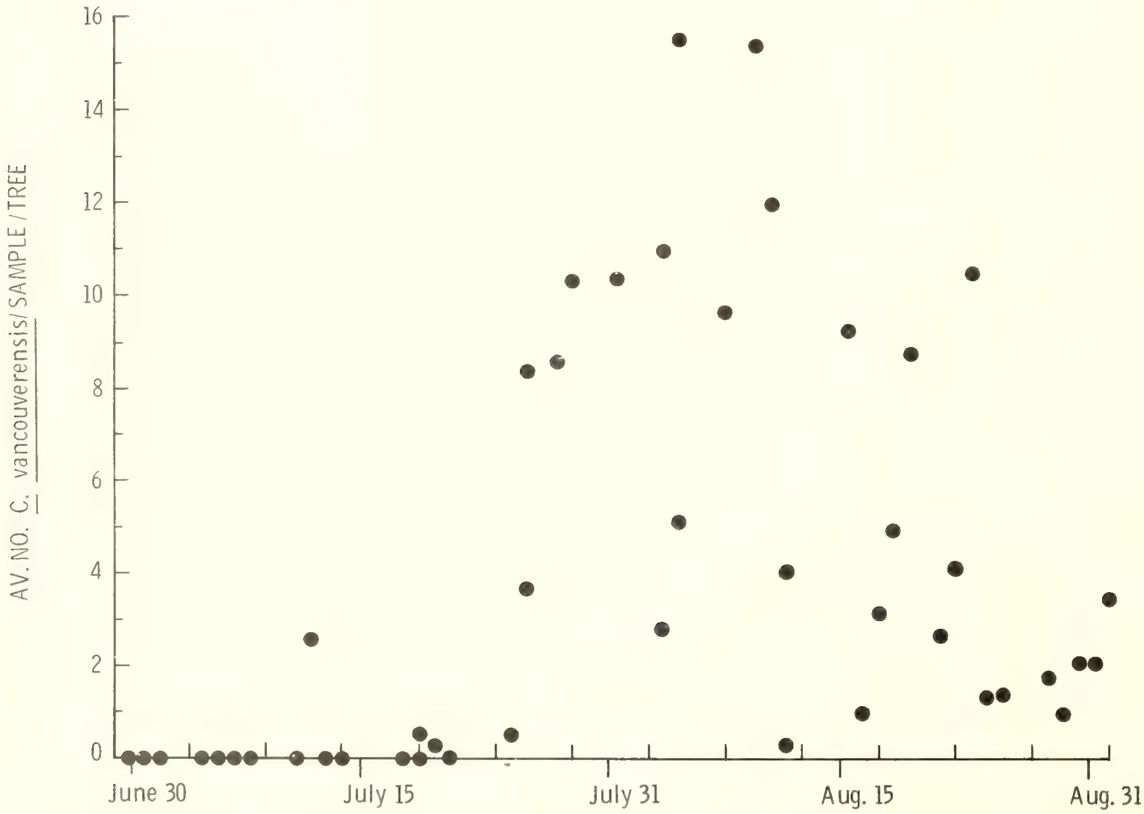

Figure 18.--Average number of *C. vancouverensis* per sample per tree by day of the year on which the tree was sampled.

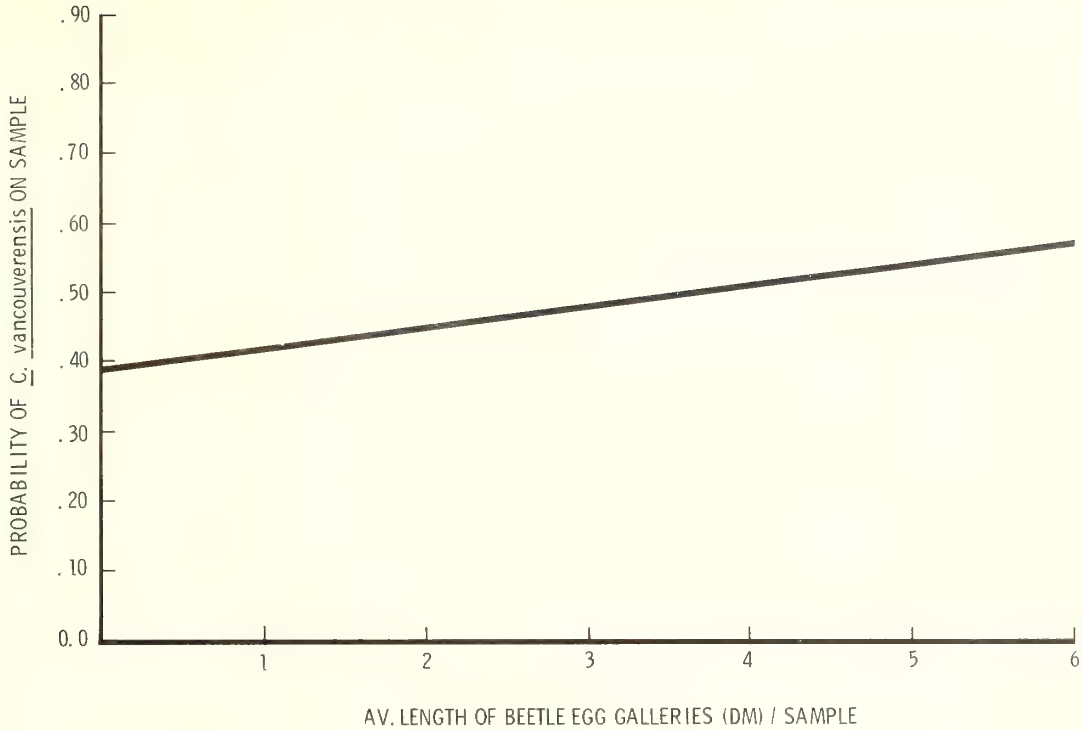

Figure 19.--Probability of *C. vancouverensis* on a sample as a function of length (dm) of Douglas-fir beetle egg galleries per sample.

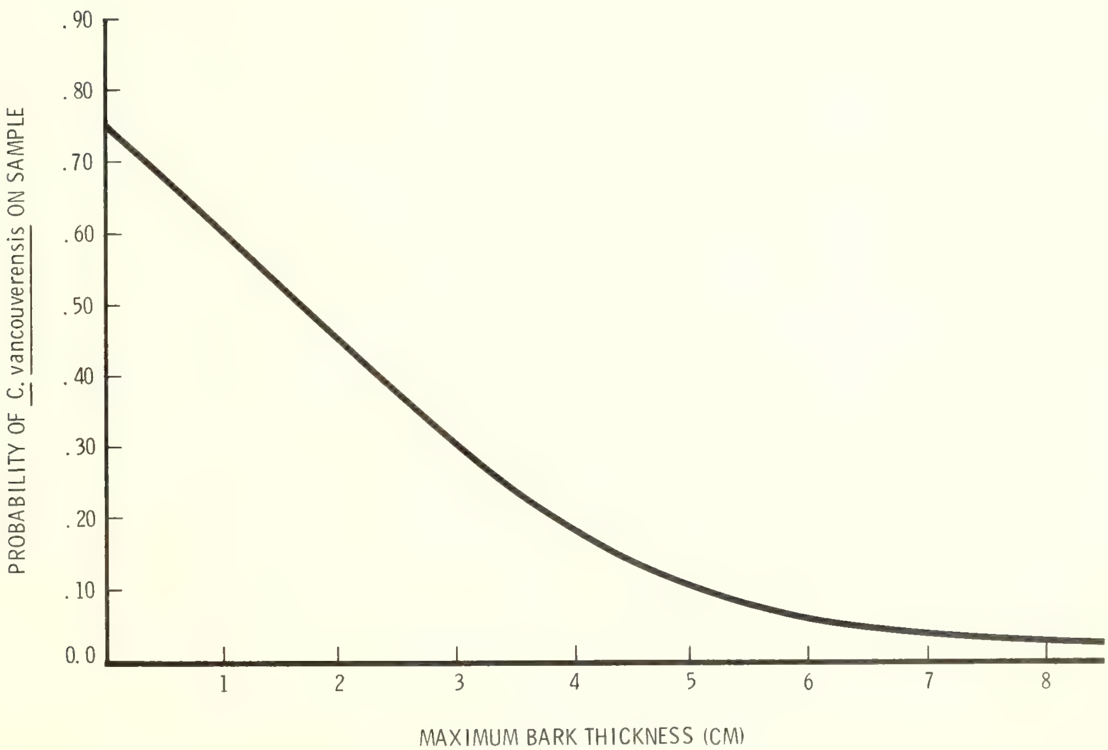

Figure 20.--Probability of *C. vancouverensis* on a sample as a function of maximum bark thickness.

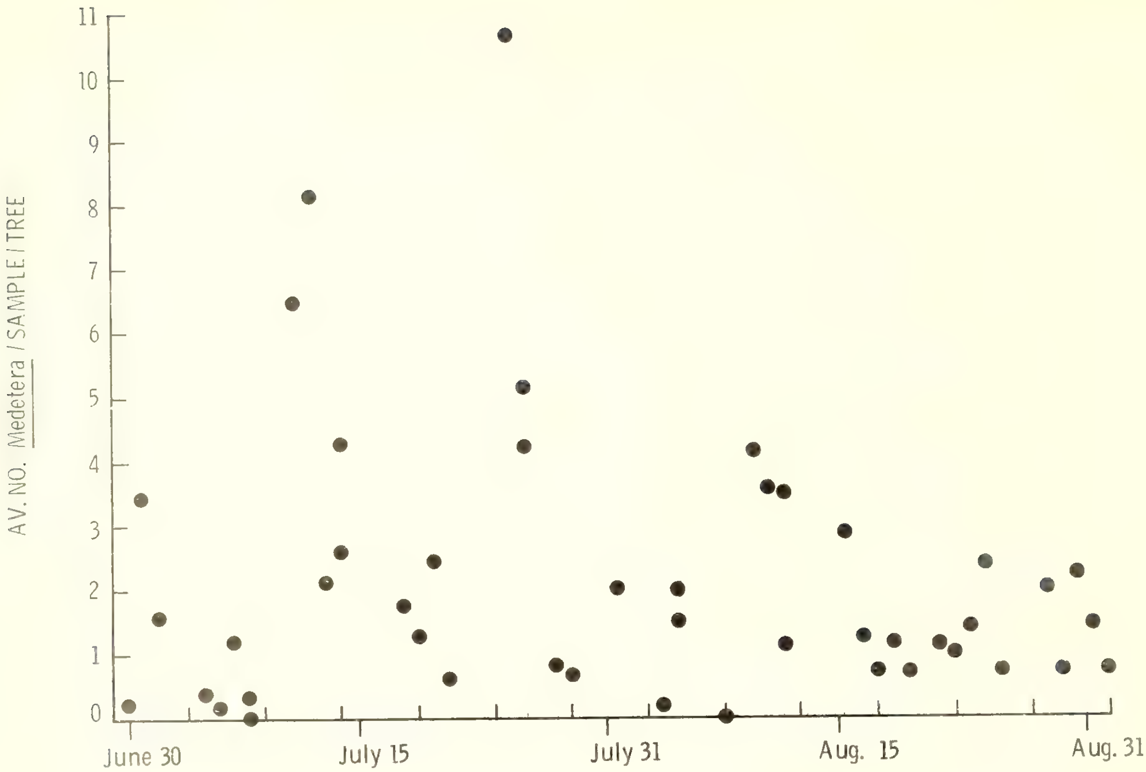

Figure 21.--Average number of *Medetera spp.* per sample per tree by day of the year on which the tree was sampled.

b_0 = -65.0992	b_5 = +1.16607
b_1 = +0.57756	b_6 = -0.183806
b_2 = -0.001366	b_7 = +0.620687
b_3 = +0.169242	b_8 = -0.057379
b_4 = -0.0081439	b_9 = +0.05076

The model closely fits the observed distribution of *Medetera* (chi-square 12.82, table 5). In examining the form of the model, we will discuss the sample variables individually, then jointly.

The probability of *Medetera* occurring on a sample in relation to changes in maximum bark thickness is shown in figure 22. All other variables in the model are held at their average values. The form of the curve fits our observations that *Medetera* were rare at upper heights where bark is thinner. We also know that *Medetera* were more abundant than average at the 4.6 m level. The peak of the curve occurs at about 3.25 cm, half way between the average maximum bark thickness for the 4.6 m and 1.5 m samples. The decline in abundance of *Medetera* where bark was thicker than 3.25 cm is due to the influence of 1.5 m samples (av. 3.90 cm max. bark thickness), there being fewer Douglas-fir beetle attacks and progeny at that sample height (Furniss 1962b). *Medetera* decreased in density with sample height (fig. 23) and increased with diameter (fig. 24) at the sample location.

Table 5.--Number of samples containing *Medetera spp.* as a function of the expected frequency and chi-square values for degree of agreement between the expected and observed frequencies

Class	Probability of presence of *Medetera spp.*	Number of samples	Number of samples with *Medetera spp.*	Expected number of samples with *Medetera spp.*	Chi-square
1	0.0 - 0.01	4	0	0.0	0.02
2	.01 - .05	16	1	.4	1.02
3	.05 - .10	8	2	.5	3.98
4	.10 - .15	13	4	1.6	3.45
5	.15 - .20	15	2	2.6	.13
6	.20 - .25	14	2	3.1	41
7	.25 - .30	12	2	3.3	.51
8	.30 - .35	8	3	2.7	05
9	.35 - .40	12	3	4.6	56
10	.40 - .45	14	5	6.0	.16
11	.45 - .50	18	5	8.5	1.50
12	.50 - .55	27	13	14.1	09
13	.55 - .60	20	11	11.5	.02
14	.60 - .65	30	22	18.9	55
15	.65 - .70	27	18	18.2	.00
16	.70 - .75	33	23	23.9	04
17	.75 - .80	37	29	28.6	.00
18	.80 - .85	25	23	20.7	26
19	.85 - .90	24	22	20.9	.06
20	.90 - .95	14	13	12.9	.00
21	.95 - 1.00	1	1	1.0	.00
Total					12.82

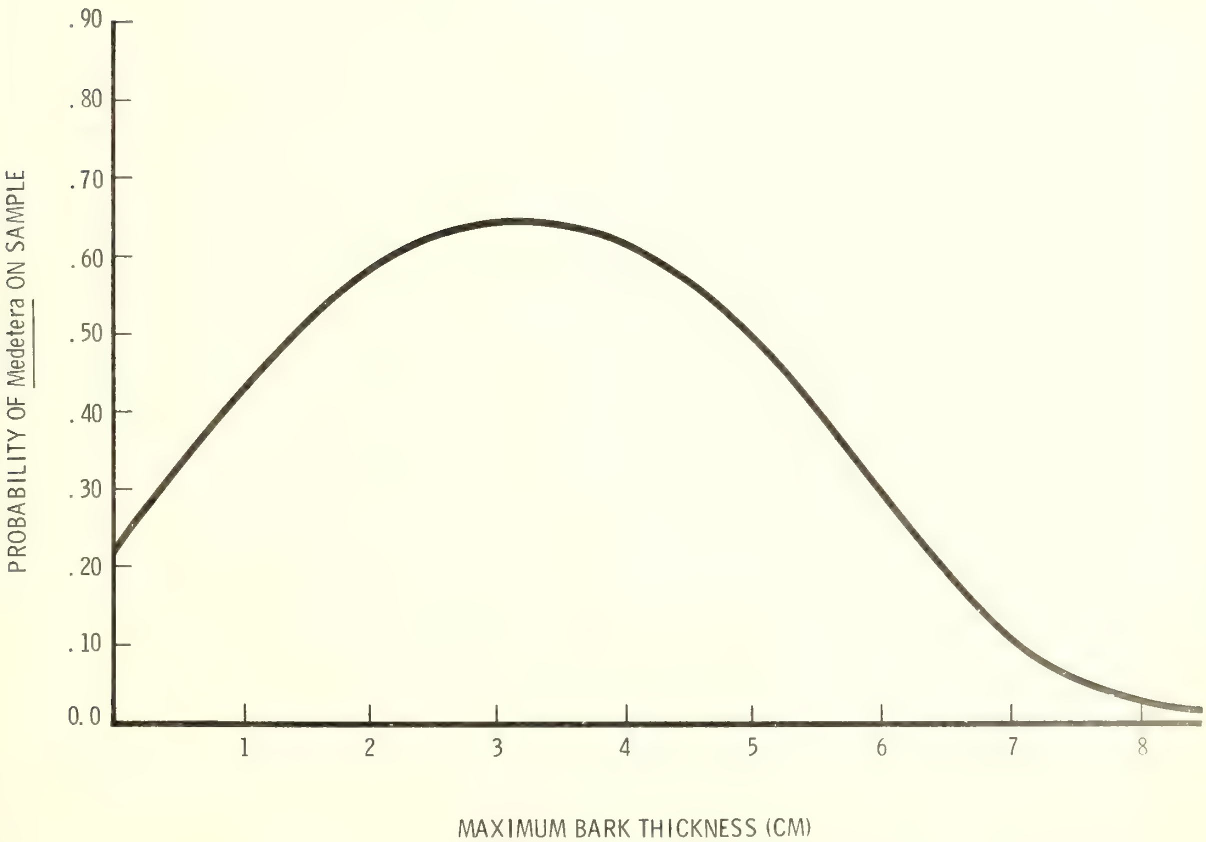

Figure 22.--Probability of *Medetera spp.* on a sample as a function of maximum bark thickness.

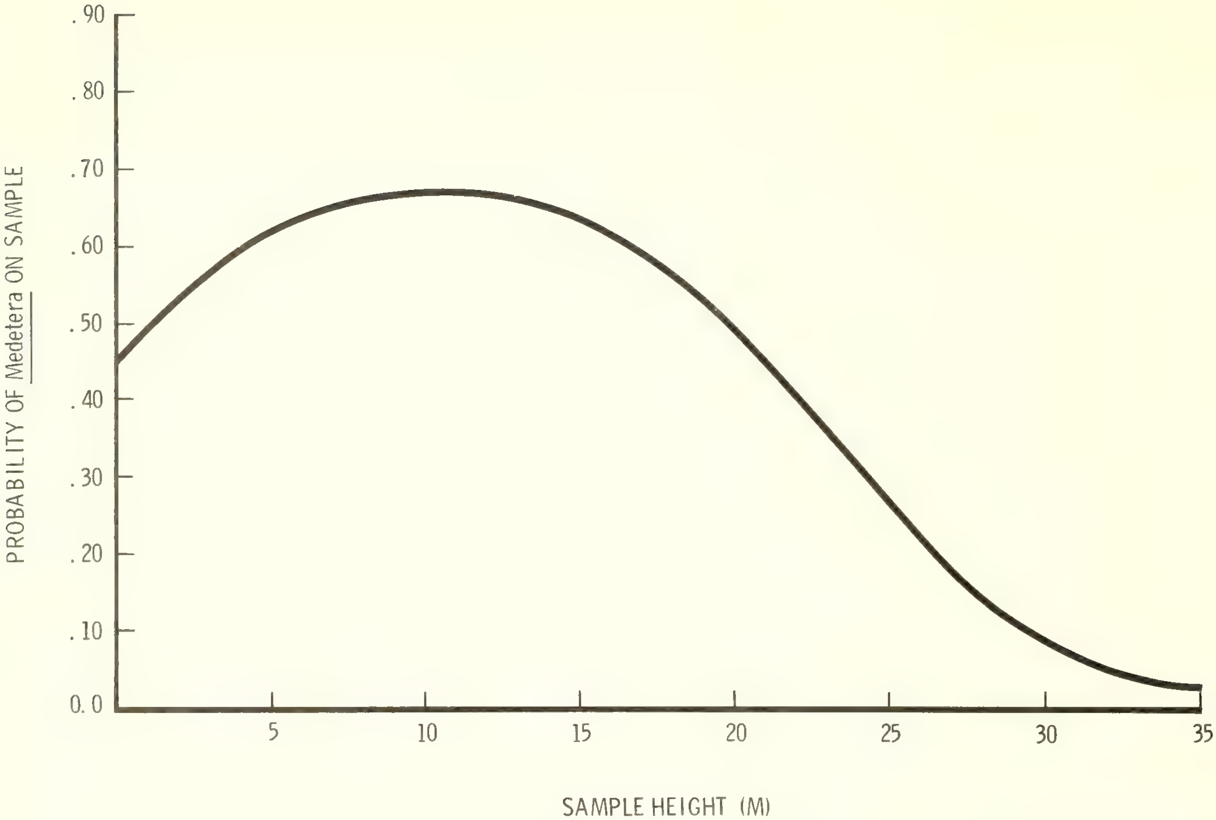

Figure 23.--Probability of *Medetera spp.* on a sample as a function of sample height.

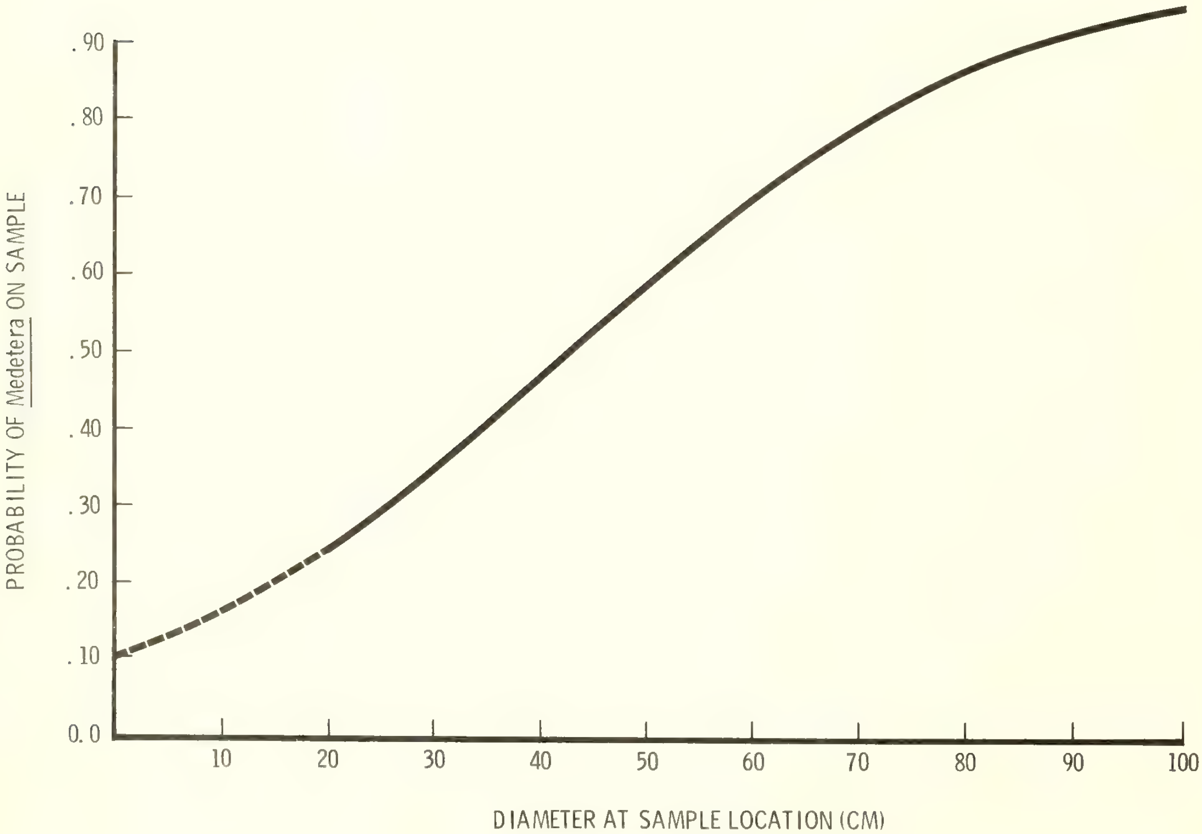

Figure 24.--Probability of *Medetera spp.* on a sample as a function of tree diameter at the sample location.

The relationship between *Medetera* and Douglas-fir beetle ventilation holes is shown in figure 25. Low numbers of ventilation holes probably indicate a low Douglas-fir beetle density and few opportunities for the predators to oviposit and to locate prey in order to survive. On the other hand, very numerous ventilation holes may have exceeded the capability of this particular *Medetera* population to exploit them as oviposition sites.

The effect of date of sample is seen in figure 26. This function may be influenced by a few trees sampled in mid-summer that had a very high density of *Medetera spp.* The subsequent decline in *Medetera,* however, might be due to drying of phloem as the season progressed, which would likely take a toll of *Medetera* larvae, especially in areas of thinner bark.

The joint effect of the physical variables that describe the sample location on a tree are seen in figure 27. Here date and number of ventilation holes are held at their average values. The diameter, maximum bark thickness, and height are values for this average tree. At heights up to 13.7 m, the probability of finding *Medetera spp.* is high (73-86 percent). As the samples are taken at heights above 14 m, the probability that *Medetera spp.* are present declines.

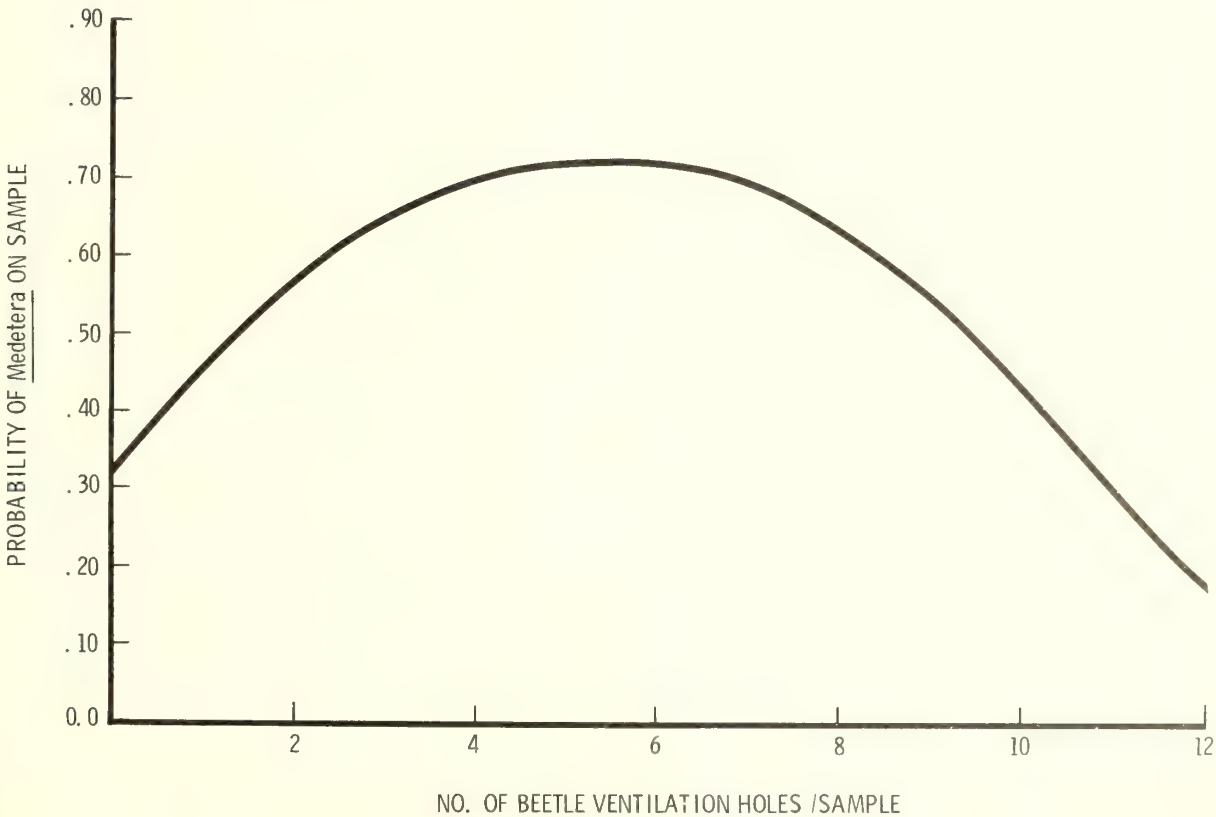

Figure 25.--Probability of *Medetera spp.* on a sample by number of Douglas-fir beetle ventilation holes per sample.

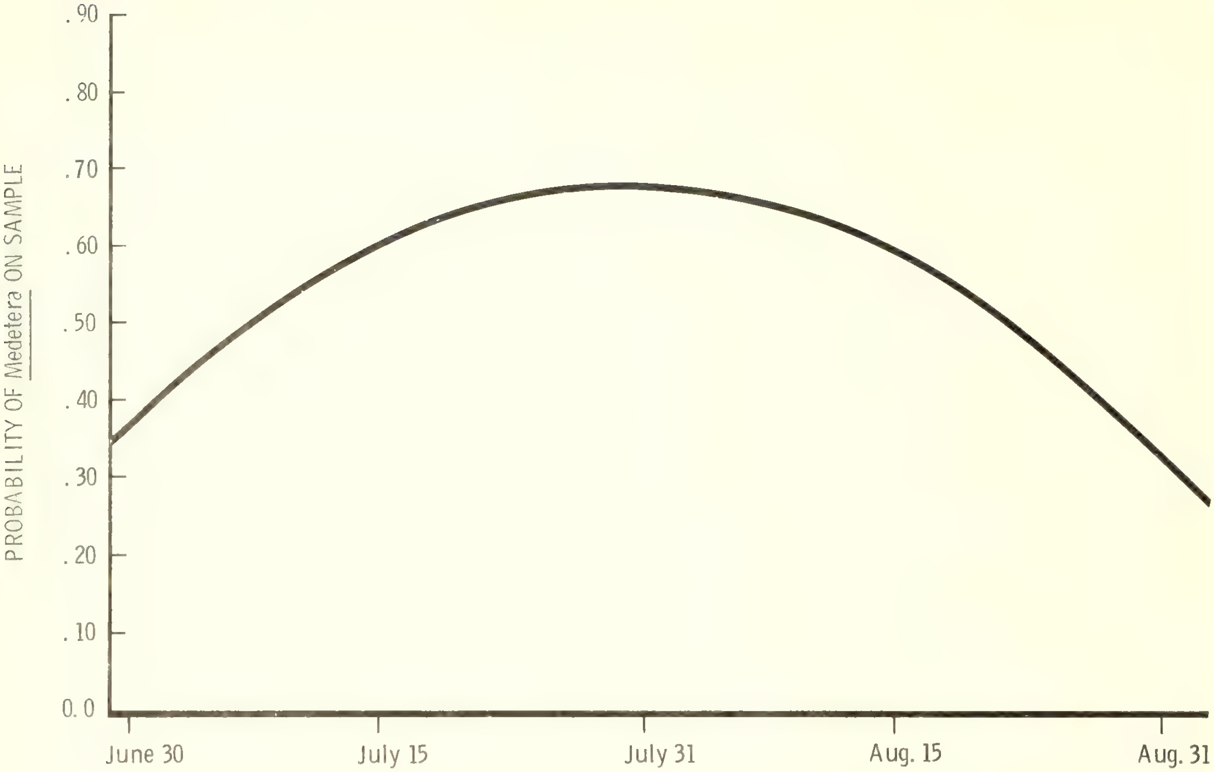

Figure 26.--Probability of *Medetera spp.* on a sample by day of the year on which the sample was taken.

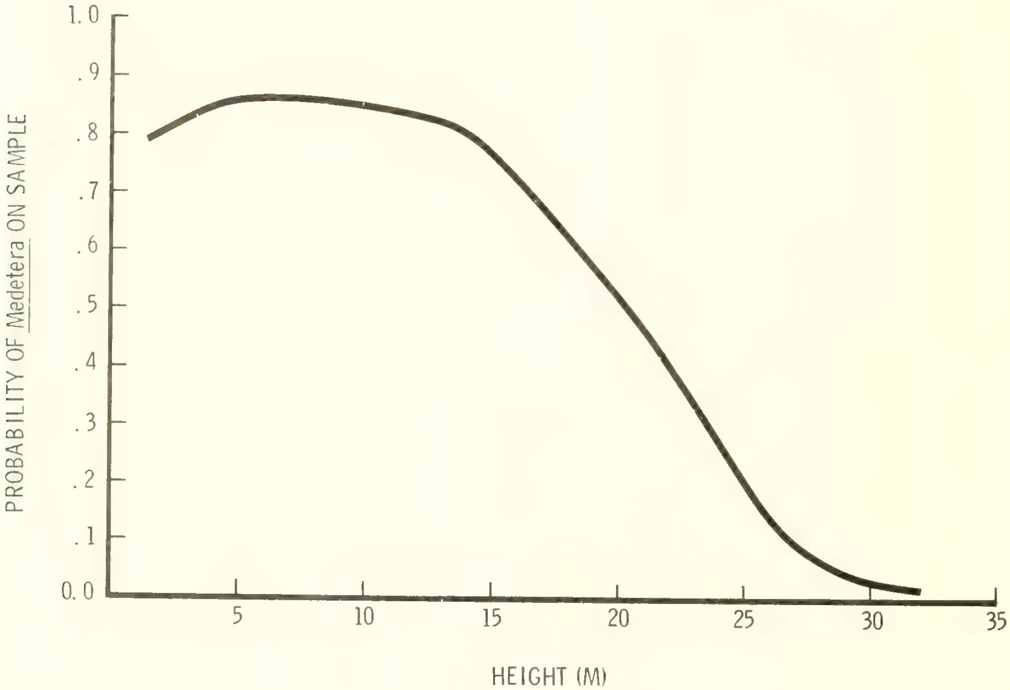

Figure 27.--Probability of *Medetera spp.* on samples on a tree using all sample variables in the prediction function.

Effect of Predators and Parasites on Douglas-fir Beetle Density

How many DFB progeny do predators and parasites kill? Because progeny are consumed, mortality cannot be measured directly. But mortality can be estimated if the number of Douglas-fir beetles per sample is viewed as a function of length of egg gallery and number of predators and parasites. This relationship can be expressed as follows:

$$y_{ij} = B_0 + \sum_{k=1}^{8} B_k X_{kij} + e_{ij}$$

Y_{ij} = number of the Douglas-fir beetle found in the jth sample of the ith tree,

X_{kij} = number of the kth predators or parasites found in the jth sample of the ith tree, (k = 1, 2,. . ., 7),

X_{8ij} = length of egg galleries (dm) found in the jth sample of the ith tree.

The predators and parasites are identified as follows:

X_{1ij} = *E. sphegeus*
X_{2ij} = *T. undatulus*
X_{3ij} = *T. chlorodia*
X_{4ij} = *C. vancouverensis*
X_{5ij} = *Roptrocerus sp.* and *Cecidostiba* spp.
X_{6ij} = *Medetera spp.*
X_{7ij} = *Belosta albipilosa*

The coefficients (B's) are estimated by linear regression. Regression coefficient/significant level (using the t-test are):

B_0 = +4.472/.001
B_1 = +0.062/.891
B_2 = -3.690/.047
B_3 = -0.670/.299
B_4 = -0.392/.001
B_5 = -0.797/.081
B_6 = -0.274/.074
B_7 = -1.834/.001
B_8 = +3.9016/.001

The degree of fit of this function is indicated by multiple correlation coefficient $R^2 = 0.24$ and a standard deviation of 9.325. The regression function has accounted for 24 percent of the variation in the number of Douglas-fir beetles per sample. Most coefficients in the equation are of correct sign as indicated by their supposed effect, but the magnitude of the coefficients is smaller than expected. For example, *C. vancouverensis* is a parasite, so the coefficient B_4 should approach -1.0 (one less Douglas-fir beetle per sample for each *C. vancouverensis* per sample). The coefficient B_1 is of the wrong sign and is essentially zero. Both B_1 and B_3 are not significantly different from zero using Student's t-test and $\alpha = 0.10$ level for testing.

If coefficient B_8 for length of egg galleries was closer to 11.26, the coefficients of the other terms could be interpreted as the efficiency of that predator or parasite. The ratio of DFB progeny to length of egg galleries, under low pressure from entomophagous insects, is 11.26. Under this condition mortality would be $B_8 X_{8ij} - Y_{ij}$. At any value of $B8$, however, the coefficients still measure the relative effectiveness of one predator to another.

SAMPLING RECOMMENDATIONS

Measurements of Douglas-fir beetle attacks and survival provide useful population indices, which foretell tree mortality prior to fading of trees (Furniss and others 1979). When tempered with weather data and stand susceptibility, population measurements could alert forest managers of the need for intensive surveys and management actions up to a year ahead of present aerial detection surveys.

But where should samples be located? When should sampling occur and how many samples are needed? Some of these questions have been addressed before (Furniss 1962a, b; 1964). Samples taken closest to the time of emergence of beetle progeny will be correlated best with surviving population level (Furniss 1964). Fall sampling, however, is a practical compromise because mortality rate is fairly stable by then and work is more easily accomplished because roads are more accessible and weather is better than in early spring.

There is no single location in a tree that is representative of beetle attacks, progeny, and entomophagous insects. Due to the particular distributions of the Douglas-fir beetle and its two most abundant parasites and predators, future sampling should consist of a minimum of three locations per tree: (1) 4.6 m, (2) midpoint of the infested stem, and (3) about 3 m below the top of the infested stem to avoid the characteristic resinous, unsuccessful zone occurring near the top (Furniss 1962b). Using those sample locations, we calculate that it would require 4 and 30 trees to estimate average densities of progeny and egg galleries, respectively, per sample per tree, with $CV_{\bar{x}} = 0.20$.

If trees cannot be felled for sampling, an alternative might be to sample at 4.6 m height with a ladder and adjust average beetle density with a regression estimator, which in our study was $Y_i = 0.750 + 0.580 X_i$. In that case, we would have needed to sample 6 and 30 trees to estimate progeny and egg galleries, respectively, at the 4.6 m height with a $CV_{\bar{x}} = 0.20$. The sampler should note, however, that the regression estimator may differ in other infestations requiring additional sampling to calculate the regression coefficients.

The question of sampling individual species of entomophagous insects is more difficult. The problem is complicated by low densities of some; seasonal variations in their presence or absence; and their distributions. Accordingly, the sampler cannot assess them collectively at any one time or location. In order to measure their effects (density of surviving beetle progeny), however, sampling should occur after mortality has leveled off at the end of summer.

Nonetheless, if we take our samples from the three recommended heights, the numbers of trees required for a $CV_{\bar{x}} = 0.20$ for the seven categories of entomophagous insects are:

Coeloides	47 (37)[1]
Medetera	28 (27)
Ecoclerus	67 (64)
Thanasimus	595 (132)
Temnochila	37 (29)
Roptrocerus, Cecidostiba	85 (76)
Belosta	67 (56)

[1]For comparison, numbers in parentheses are samples needed using data from 3-m intervals instead of three samples per tree.

CONCLUSIONS

The mathematical model based on the logistic function represents realistically the seasonal abundance of Douglas-fir beetle progeny in relation to regulatory factors involving entomophagous insects and sample characteristics. The model is useful for demonstrating the general importance of parasites and predators in the post-egg-hatch period. For example, average mortality of Douglas-fir beetle progeny after egg hatch in successfully attacked trees was 58 percent. Further improvement in the model should be directed toward separation of the proportional mortality due to entomophagous insects and that due to competition among progeny.

The information presented on the temporal and spatial distribution in trees of the Douglas-fir beetle and its major enemies will facilitate evaluation of infestations and development of an improved pest management program. Such a program will need to include information on susceptibility of surrounding trees and stands because that factor limits the amount of mortality that a particular population can cause. Research at this Station, in cooperation with Forest Service Region 1, and Idaho Department of Lands, is being directed to meet that need.

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Regression models were developed to predict abundance of Douglas-fir beetles in relation to entomophagous species, date, and sample characteristics. Probability of presence of entomophagous insects on samples was determined with the logistic function. Predation and parasitism were estimated to have caused 58 percent mortality of progeny during the summer.

KEYWORDS: Douglas-fir beetle, parasites, predators, sampling, modeling, logistic function.

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Intermountain
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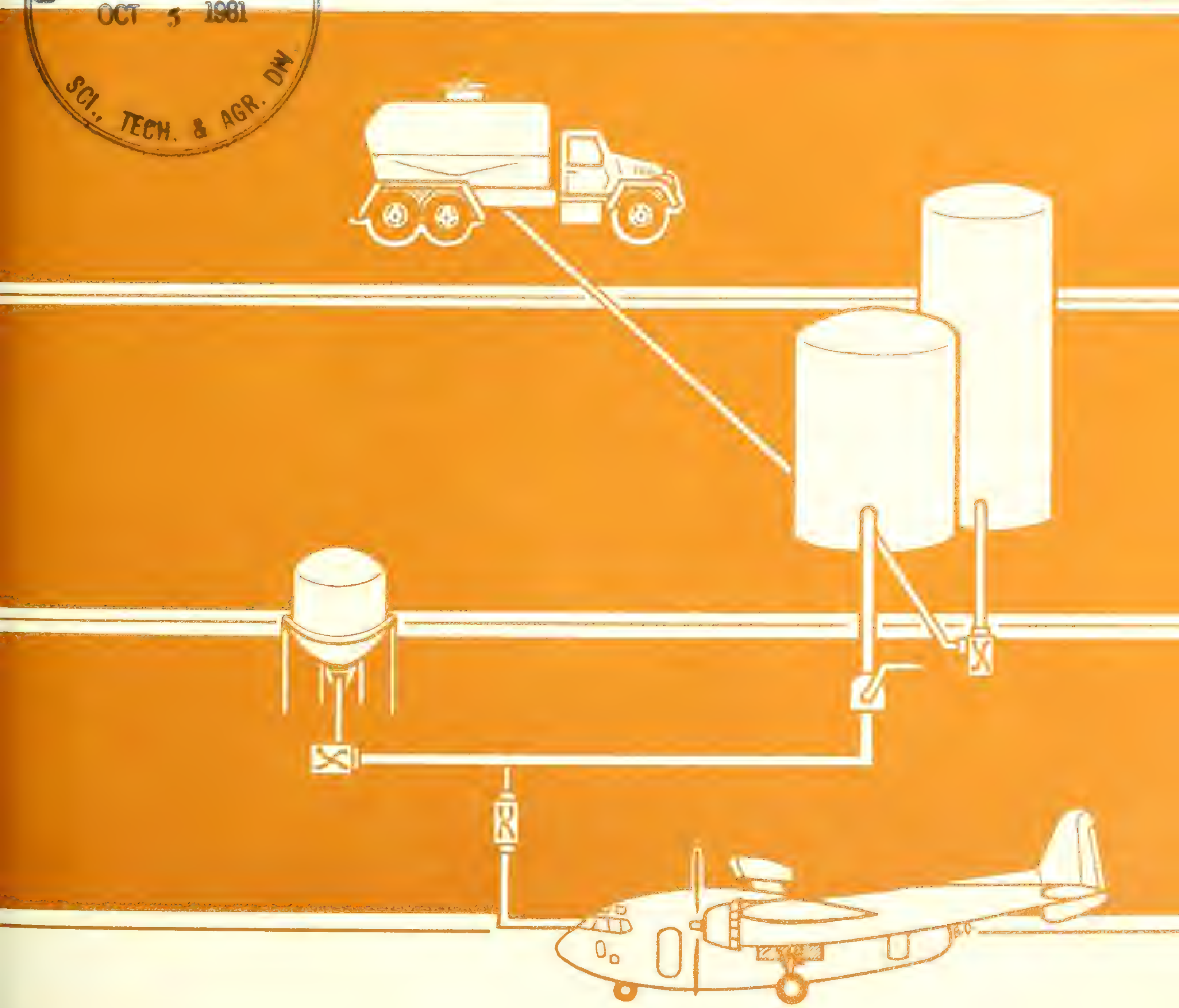
General Technical
Report INT-112

August 1981

Evaluation Of Megatard 2700: A Proposed New Fire Retardant System

Charles W. George and Cecilia W. Johnson



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RESEARCH SUMMARY

This report discusses a proposed new fire retardant system and the laboratory analysis and evaluation of the retardant solution produced. The proposed system utilizes ammonium sulfate, delivered dry and liquified at the base, as the active fire retardant salt. For use, the ammonium sulfate liquid concentrate is diluted with water, a gum-thickening agent added, and the final solution delivered to the aircraft as needed. By using alternative thickening packages, the user can have a choice of uncolored or colored retardant.

Attention is given to the physical and chemical characteristics and performance of the final retardant solutions with emphasis on mixing, hydration and viscosity development, solution stability, corrosivity, and effectiveness.

Suggestions supported by performance data are presented for potential product improvements especially in regard to formulation corrosivity. Recommendations are made for additional evaluation including operational testing and a cost-to-benefit (value) analysis.

CONTENTS

United States Department of Agriculture

Forest Service

Intermountain Forest and Range Experiment Station

General Technical Report INT-112

August 1981

Evaluation Of Megatard 2700: A Proposed New Fire Retardant System

BACKGROUND

Omega Chemical Compounding International approached the USDA Forest Service in November 1976 with a proposal to provide a new retardant product utilizing concepts in chemical, storage, and mixing systems different from what was currently in use.[1] Omega thought the new retardant system might fulfill Forest Service needs for a less expensive but effective retardant that could be simply, reliably, and accurately mixed with a minimum of equipment and manpower.

Omega's proposed product was a two-component system combined with water, which produced a thickened product that could be loaded directly into an airtanker. The retardant component contained ammonium sulfate and corrosion inhibitor that would be supplied in dry form by the truckload and liquified upon delivery to the tanker base. The liquified ammonium sulfate, containing the corrosion inhibitor, would then be stored as a 28 percent ammonium sulfate solution. The second component, containing the thickening agent, bacteriacide, and coloring agent (if desired) would be supplied in 1-ton bulk containers, stored dry, and added to the water stream. The thickened water would be mixed with an equal volume of the liquid ammonium sulfate component as it was loaded into the airtanker. A simplified schematic of the system is shown in figure 1.

This system had a potential for reducing costs because ammonium sulfate costs less than half as much as diammonium phosphate.[2]

[1]Letter to N. Anderson, USDA Forest Service, from L. E. Beightol, Omega Chemical, dated November 22, 1976, containing a "Proposal to USDA Forest Service – submitted by Omega Chemical Compounding International, Glendale, Arizona," 11 pages on file at the Northern Forest Fire Laboratory, Missoula, Mont.

The first step in evaluating the system was to determine the suitability and performance of the final chemical retardant product. Although operational performance depends in part on hardware performance (mixing accuracy and reliability), the components when prepared and mixed under ideal conditions must perform adequately. The Northern Forest Fire Laboratory undertook a cooperative research and development program with Omega to determine certain performance characteristics and to provide data necessary for evaluation.[3]

The components and the retardant produced by the proposed Omega system do not fit either existing Forest Service retardant specification (liquid, unthickened, or dry, thickened) (USDA Forest Service 1975, 1977). The primary deviations are:

1. One component is stored as a liquid and one is stored dry; the mixed product is thickened.

2. The system is designed to provide mixed retardant to the aircraft on demand, with no storage outside of the aircraft. The length of storage varies according to operational considerations.

To determine the suitability of Omega's Megatard 2700 retardant system, studies were conducted to quantify the performance of the separate components and the mixed retardant. The primary study included but was not limited to areas described in present retardant

[2]"Chemical Marketing Report," June 7, 1978, through June 19, 1979, lists the price of standard grade ammonium sulfate in car lots as $60/ton, and feed grade diammonium phosphate as $240/ton.

[3]Cooperative Proposal and Agreement, Intermountain Forest and Range Experiment Station and Omega Chemical Compounding International, August 16, 1977, on file at Northern Forest Fire Laboratory, Missoula, Mont.

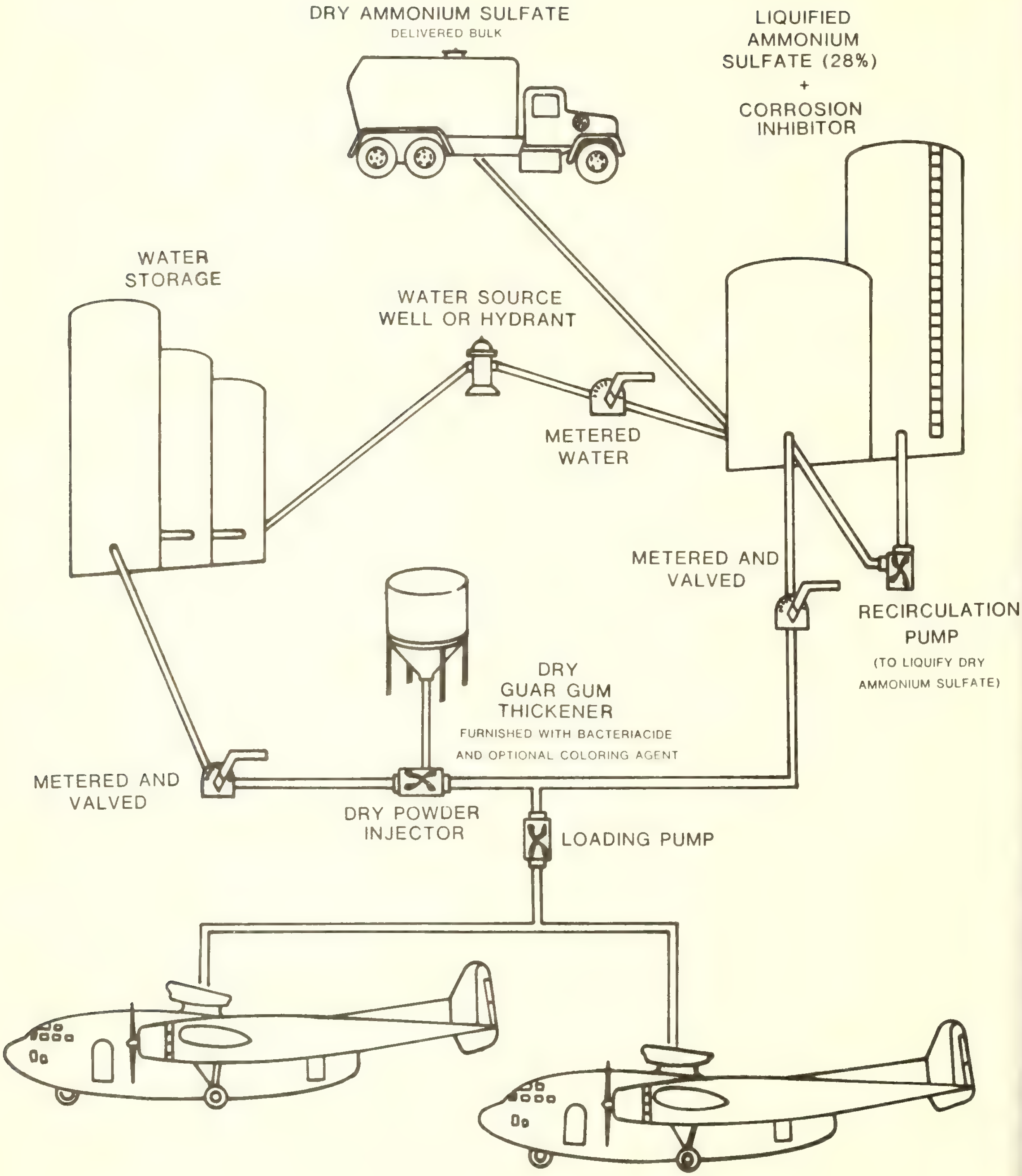


Figure 1.—Simplified schematic of proposed Omega retardant mixing and transfer system.

specifications where specific requirements exist. The performance requirements in the two specifications are not identical due in part to differences in handling and use of the product. The requirements therefore were used only as a guide. A discussion of specific conditions of the proposed methods for handling, storage, and use is included in this paper. Also, the test procedures varied, making it necessary to define performance in a manner not directly relatable to performance required in the specification. In areas where current research programs and results provide additional insight to the performance, a more in-depth discussion is presented.

This report documents the test procedures and results of evaluations performed at the Northern Forest Fire Laboratory in Missoula, Mont.

PRODUCT DESCRIPTION

Two slightly different products, Megatard 2700A and Megatard 2700B, were formulated for the Omega retardant system. Both contain ammonium sulfate as the active fire retardant salt, a guar gum thickener, iron oxide for color, a spoilage inhibitor for the guar gum, and corrosion inhibitors. The only difference between the two products is the type of corrosion inhibitor used: Megatard 2700A contains ammonium thiocyanate and 2700B contains sodium ferrocyanide. The dry component can be supplied with or without the iron oxide coloring agent as specified by the user. A significant change in performance is not anticipated due to removal of the iron oxide. The approximate composition of the formulations and components is given in table 1.

Table 1.—Composition of Megatard formulations and components[1]

Liquid component - percent by weight	Dry component - percent by weight
MEGATARD 2700A	
Ammonium sulfate - active retardant, 28 percent	Guar gum-thickener, 78 percent
Ammonium thiocyanate - corrosion inhibitor, 2 percent	Iron oxide - coloring, 18 percent
Water, 70 percent	Spoilage inhibitor, 4 percent
MEGATARD 2700B	
Liquid component - percent by weight	**Dry component - percent by weight**
Ammonium sulfate - active retardant, 28 percent	Guar gum-thickener, 78 percent
Sodium ferrocyanide - corrosion inhibitor, 2 percent	Iron oxide - coloring, 18 percent
Water, 70 percent	Spoilage inhibitor, 4 percent

[1]To mix the Megatard 2700 formulations, the dry component is added to water at a mix ratio of 0.244 lb per gallon of water. The water containing the dry "thickener component" is added in equal volumes to the inhibited 28 percent ammonium sulfate solution (undiluted liquid component).

We received the test sample of Megatard 2700A on June 20, 1977. It consisted of both components in dry form. The ammonium sulfate and corrosion inhibitor were subsequently dissolved in water as would be done by the supplier upon delivery to the base. This provided an opportunity to observe the rate and ease of dissolution of the "liquid component." We received the sample of Megatard 2700B on March 28, 1978. The ammonium sulfate was in liquid component form to be mixed using the same dry component as the earlier sample. (As previously noted, the 2700B liquid component also contained a different corrosion inhibitor.)

We stirred the dry retardant salt/corrosion inhibitor mix for Megatard 2700A into water to form the "liquid component." The ammonium sulfate and inhibitor were easily dispersed and readily soluble with little agitation. The dry component (the color, thickener, and spoilage inhibitor) was mixed with water by simple stirring to form a slurry. This was easily done with rapid dispersal of dry component into the water without clumping or coagulation. Equal volumes of the two solutions were blended immediately to make the "mixed retardant" ready for loading, as would be done operationally.

LABORATORY PERFORMANCE CHARACTERISTICS OF MEGATARD 2700A AND 2700B

The two products were tested for performance using the general procedures and requirements outlined in the USDA Forest Service Specifications, 5100-00301a and 5100-00302b (1975, 1977). The general requirements are given at the beginning of each of the following "Qualification Requirements" sections.

Storage

Dry Chemical Requirement (301): The dry retardant material stored indoors in sacks or bulk for a period of 1 year must be capable of meeting all the requirements listed in 3. The dry retardant, mixed with water according to retardant proportions specified by the manufacturer, shall meet the requirements of 3.3 through 3.16.

Liquid Chemical Requirement (302): The liquid concentrate chemical after being stored in 10-gallon, mild steel containers, outdoors under environmental conditions at Missoula, Mont., and San Dimas, Calif., for a period of 1 year, shall meet all other requirements listed in 3.3 through 3.15. The liquid concentrate mixed with water according to retardant proportions specified by the manufacturer, shall meet the requirements of 3.4 (viscosity), 3.12 (separation), and 3.13 (spoilage) after it has been mixed and then stored as specified in 4.3.1.2 ("mixed retardant") for a period of 4 hours.

Performance: One-year storage tests of Megatard 2700A liquid component and the mixed retardant were initiated in Missoula, Mont., and San Dimas, Calif., as per specified procedures. Throughout the year the test samples were examined visually for evidence of separation or deterioration as well as attack by the retardant on

Table 2.—Characteristics of Megatard 2700A prior to and following storage

MEGATARD 2700A PRIOR TO STORAGE		
Property	**Liquid component**	**Mixed retardant**
Salt content [%$(NH_4)_2SO_4$] Kjeldahl analysis	30.65	15.06
Density (g/cc)	1.171	1.088
Viscosity (centipoise)	15	1040
pH	5.5	6.9

MEGATARD 2700A FOLLOWING 1-YEAR OUTDOOR STORAGE - MISSOULA, MONT.				
Liquid component	**Top**	**Middle**	**Bottom**	**Mixed**
Salt content [%$(NH_4)_2SO_4$] Kjeldahl analysis	27.88	27.75	27.76	28.08
Density (g/cc)	1.169	1.169	1.168	1.169
Viscosity (centipoise)	6	6.5	6.5	5.5
pH	6.87	5.90	7.32	5.34
Mixed retardant				
Salt content [%$(NH_4)_2SO_4$] Kjeldahl analysis	10.58	14.30	15.16	14.29
Density (g/cc)	1.065	1.090	1.101	1.090
Viscosity (centipoise)	80	180	710	210
pH	7.31	6.78	6.77	6.70

MEGATARD 2700A FOLLOWING 1-YEAR OUTDOOR STORAGE - SAN DIMAS, CALIF.				
Liquid component	**Top**	**Middle**	**Bottom**	**Mixed**
Salt content [%$(NH_4)_2SO_4$] Kjeldahl analysis	27.88	27.92	28.15	27.87
Density (g/cc)	1.166	1.166	1.167	1.165
Viscosity (centipoise)	8	6	7	7
pH	7.37	7.46	7.50	7.43
Mixed retardant				
Salt content [%$(NH_4)_2SO_4$] Kjeldahl analysis	14.39	14.44	14.45	14.45
Density (g/cc)	1.087	1.086	1.093	1.090
Viscosity (centipoise)	41	44	115	55
pH	7.28	8.36	7.84	7.65

the storage container. General appearance was also noted when the storage containers were opened. At the end of 1 year the containers were opened and samples drawn from the top, center, and bottom of each container. All remaining retardant was stirred together. Analyses of Megatard 2700A samples for salt content, density, viscosity, and pH were conducted. The results are shown in table 2. (Other analyses conducted on these samples, such as corrosion, are discussed in later sections of this report.)

A yellow powdery substance that might be part of the inhibitor floated on the surface of the fluid during the year. Some of the fluid also "crawled" out of the can even though the lid had been sealed with a silicone caulking and tightened with bolts. A crust built up to about 1/2-inch thick on the lid by the end of the year. This phenomenon is characteristic of ammonium sulfate solutions and is commonly observed at Fire-Trol 100 retardant bases. Upon removal of the lid we noticed a strong odor of hydrogen sulfide, likely due to attack of the mild steel by the solution.

The results of chemical and physical tests indicate the liquid component did not change significantly during the year and that it remained uniform throughout the entire container. This is a definite advantage since systematic routine recirculation would not appear necessary. The mild steel storage container, however, showed significant deterioration especially at the liquid/vapor interface and in the vapor zone. About a cup of metal particles (flakes) were lying in the bottom of the can and most of the surface was covered with blisters of metal that had partly flaked off. Figure 2 shows the storage container showing exfoliation and localized corrosion. (The corrosive characteristics of Megatard 2700 will be discussed further under corrosion requirements.)

The mixed retardant showed about 1/2-inch of separation (out of 16 inches total) in 2 months. There was little additional visible separation over the remainder of the year although the solution did appear grainy after 6 months. Complete separation usually follows this grainy appearance, but this had not happened by the end of 1 year. When the 10-gallon storage container was opened, metal flakes floated on about one-third of the retardant surface and the container showed vapor phase corrosion similar to that of the liquid component. Tests on samples of the retardant indicated the top portion was waterlike, while the lowest 2-4 inches were sludgelike and very viscous. Although this bottom portion was thick and viscous, presumably due to settling, no hard particles were found, and slight mixing or agitation created a homogeneous mixture. Results of analysis of these samples are shown in table 2.

The variations throughout the sample may not be significant if Megatard 2700 is used operationally as designed and shown in figure 1, since Megatard 2700 will be demand-mixed and long-term storage is not likely. If storage is required, a short period of recirculation will give a homogeneous solution; although the viscosity may remain somewhat lower than in the fresh mixed retardant.

One-year outdoor storage tests of Megatard 2700B were not performed because the change in formulation (different corrosion inhibitor) is not expected to significantly affect storage characteristics of the mixed retardant. Verification of this would require 1-year indoor storage tests to monitor separation and viscosity. The analysis of the 2700B sample prior to storage is as follows:

Megatard 2700B prior to storage

Property	Liquid component	Mixed retardant
Salt content [%$(NH_4)_2$ SO_4] Kjeldahl analysis	25.43	15.51
Density (g/cc)	1.159	1.090
Viscosity (centipoise)	7	1,510
pH	6.3	6.9

(The performance of the Megatard 2700, after outside storage, during specific tests will be discussed later.)

Moisture Content

Dry Chemical Requirement (301): The moisture content of the dry retardant material shall not exceed the following values:

Retardant	Moisture content (percent by weight)
Type A Class II (aircraft application, gum-thickened)	3
Type A Class III (aircraft application, clay-thickened)	5

Liquid Chemical Requirement (302): None.

Performance: The moisture contents of the Megatard 2700A dry component (thickener and coloring agent) and the dry ammonium sulfate/inhibitor mixture, which would be liquified upon delivery at the base site under proposed operating procedures, were determined. Samples of the dry components were weighed and placed in a dessicator containing silica gel. After 24 hours the samples were weighed and then returned to the dessicator. Samples were checked regularly until the weight of each sample stabilized. The moisture content of each sample was calculated from the final and initial weights. Moisture contents of three samples were averaged in each case. The moisture content of the dry ammonium sulfate and corrosion inhibitor was 0.01 percent (by weight) and that of the dry component (thickener, color, spoilage inhibitor) was 2.3 percent (by weight). The moisture content of Megatard 2700B was not determined since the small amount of inhibitor in the dry component should not significantly change the moisture content of the salt mixture when inhibitor type is altered.

Specific Weight

Dry and Liquid Chemical Requirement (301, 302): The liquid component and the "mixed retardant" shall be tested at 70° F ± 5° by weighing a container of known volume before and after filling with retardant. The specific weight of the "mixed retardant" shall not exceed 9.5 pounds per gallon. There is no specific weight requirement for the liquid component.

Performance: All specific weights were determined by filling weighed, calibrated pycnometers with retardant at 70° F and reweighing after entrapped air bubbles had escaped. At least three replications were

Figure 2.—Liquified ammonium sulfate storage container showing exfoliation and localized corrosion.

performed on each sample. The specific weights of the liquid components at the beginning and end of the 1-year storage period were:

	Specific weight	
	Beginning of test period	After 1-year storage
	Lb/gal	*Lb/gal*
Megatard 2700A liquid component	9.77	9.75
Megatard 2700A mixed retardant	9.07	9.09
Megatard 2700B liquid component	9.67	—
Megatard 2700B mixed retardant	9.09	—

Viscosity and Deterioration

Dry Chemical Requirement (301): The "mixed retardant" when tested using a Brookfield model LVT or LVF viscometer and appropriate spindles shall reach the following viscosity 4 minutes after mixing.

Retardant	Viscosity
	Centipoise
Type A Class II	1000-2000
Type A Class III	1500-2500

A loss in viscosity of more than 25 percent during the first year will constitute unacceptable deterioration.

Liquid Chemical Requirement (302): The liquid component and the "mixed retardant" shall be tested using a Brookfield model LVT or LVF viscometer and appropriate spindles, and the viscosity values before and after the storage period recorded. The viscosity of the "mixed retardant" shall not exceed 200 centipoise. No required viscosity for liquid component. No requirement for deterioration.

Performance: The liquid component and the mixed retardant were tested using the Brookfield model LVF viscometer at the beginning and end of 1 year in

storage. The average values for each sample are given below.

	Viscosity		
	Beginning of test period	After 1-year outdoor storage	Percentage decrease in viscosity
	---------- Centipoise ---------		
Megatard 2700A liquid component	15	6	60
Megatard 2700A mixed retardant	1040	210	80
Megatard 2700B liquid component	7	—	—
Megatard 2700B mixed retardant	1510	—	—

Some concern existed that the large spread in initial viscosities might be caused by differences and nonhomgeneity in the dry retardants. The results of further testing, however, suggested that at least some of the differences in the initial viscosities were due to variations in mixing and shear rather than to variations in the products (see discussion on mixing). In common with other gum-thickened retardants, there is a minimum amount of shear required for adequate viscosity development as well as an optimum shear rate to get maximum viscosity and stability from a given quantity of gum.

Additional viscosity tests were run on two 1-quart samples of liquid component and two samples of mixed retardant set aside exclusively for viscosity tests. One sample of the liquid component and one of the mixed retardant contained a mild steel coupon, 1 inch × 1 inch × 1/8 inch (ratio of mild steel to retardant volume in average size operational storage tanks), to determine possible effects of steel on inhibitors or the active chemical. All samples were agitated prior to running the viscosity tests. These tests were run at weekly intervals throughout the 1-year test period. Variations in individual sample viscosities with and without the steel coupon were not significant and the two values were averaged. The results of these tests are shown in figure 3. Note, as previously mentioned, the difference in initial viscosity is possibly due to differences in mixing. Viscosities will be similar if identically mixed. Viscosity can be increased or decreased by varying the use level o the thickener component, as will be discussed later.

Only Megatard 2700A was stored for 1 year as re- quired by the deterioration test specified in the dr chemical, thickened specification. The mixed retardan lost 80 percent of its viscosity by the end of the year This far exceeds the allowable limit of 25 percent. Bu since Megatard 2700 was designed for demand mixin and the proposed system does not rely on storage of the mixed retardant, a 1-year storage time may be unneces- sary.

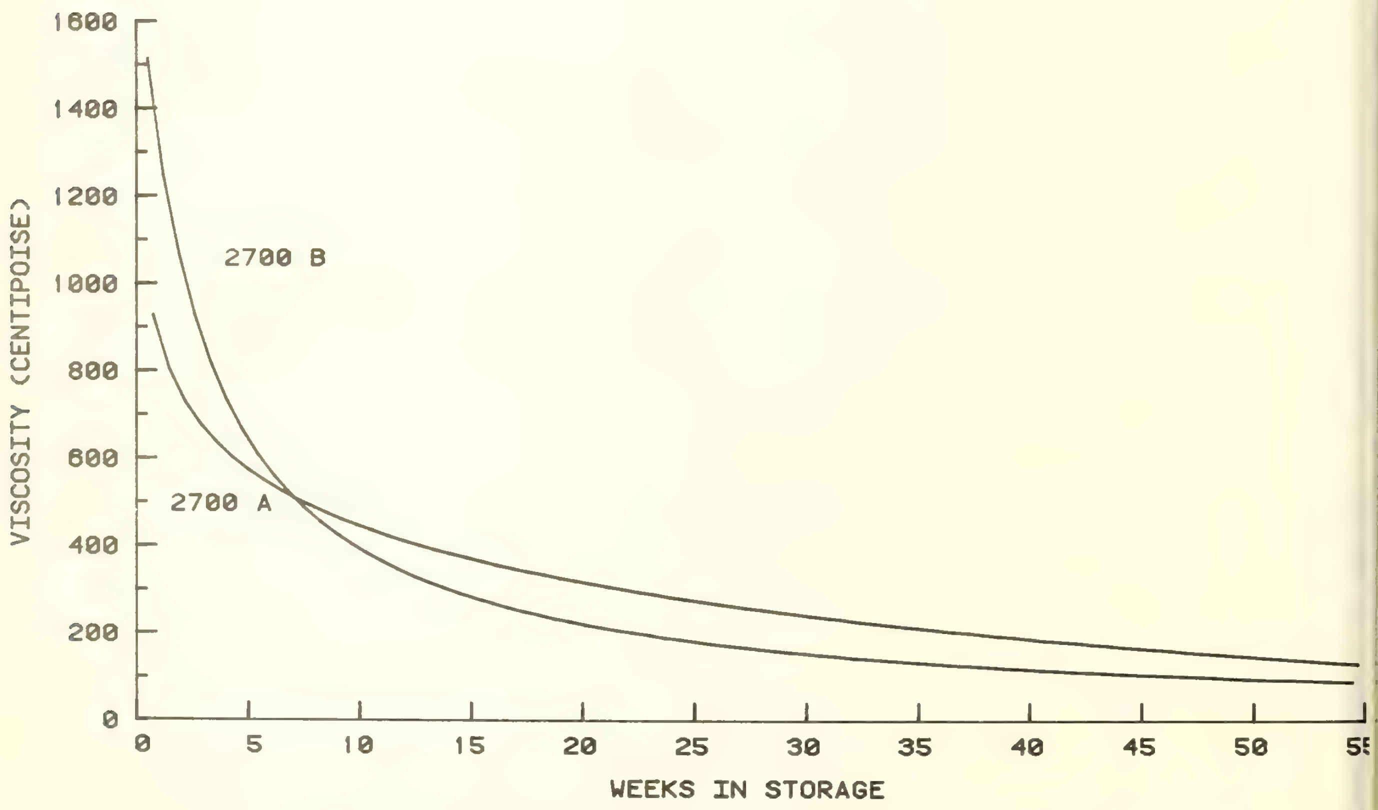


Figure 3.—Viscosity of Megatard 2700A and 2700B during 1-year storage.

A proposed USDA Forest Service specification for all retardants, whether prepared from liquid or dry components, would have reduced the long-term storage requirement to a maximum loss in viscosity of less than 25 percent over a 30-day storage period.[4] The performances of the Megatard products as per this criteria are given below and shown in figure 4.

	Viscosity: Beginning of test period	Viscosity: After 30 days storage	Viscosity: Percentage decrease in viscosity
	Centipoise	Centipoise	
Megatard 2700A mixed retardant	1870	1640	12
Megatard 2700B mixed retardant	1510	920	39

Although Megatard 2700B had a decrease of nearly 40 percent, it still had a viscosity of almost 1000 centipoise, the minimum allowed for a gum-thickened retardant. (Raising the initial viscosity by altering the mixing procedure to obtain required shear or increasing the concentration of the thickener component can raise the initial viscosity enough that the 30-day viscosity can be increased to greater than 1000 centipoise.)

To illustrate the effect of thickener concentration on retardant viscosity, we varied the amount of dry component used between 0.05 and 0.20 pounds per gallon of mixed slurry while holding mixing time and shear as constant as possible. All samples were stored for 30 days and the viscosities monitored throughout the storage period. Results of these tests are summarized in table 3 and shown in figure 5. Most samples had only a slight change in viscosity during the storage period although the samples with very low concentrations of thickener and thus very low viscosities showed greater instability during storage. In addition, slight changes in gum concentration greatly affected the viscosity. Although there were changes in viscosity during the 30 days, the changes were not significant enough to alter the relationship between the amount of thickener used and the resulting viscosity.

Properly mixed samples of Megatard 2700A and 2700B develop viscosities in the required range (1000-2000 centipoise for gum-thickened retardants) by the time that mixing is finished or within the first 4 minutes after mixing ceases.

Corrosion

Dry and Liquid Chemical Requirement (301, 302): When the liquid concentrate and the "mixed retardant" are tested using the Magna Corrater™ and 2024-T3 aluminum, AISI C-1010 steel, and naval brass (62 percent Cu, 37 percent Zn, 1 percent Sn) probe tips, the uniform corrosion rate shall not exceed 0.001 inch per year (1 mil/yr) and the pitting index shall not exceed 5.0.

[4]Proposed USDA Forest Service Interim Specification 5100-00303 for retardant, forest fire, dry or liquid chemical for aircraft or ground application, April 1976.

Table 3.—Viscosities and percent change in Megatard 2700A viscosity after 30 days storage for formulations prepared using varying amounts of the thickening component

Pound of dry component per gallon of slurry	Viscosity after 60 minutes	Viscosity after 30 days	Percent change in viscosity
	Centipoise	Centipoise	
0.050	110	100	− 9.1
.084	550	150	−72.7
.095	777	220	−71.4
.100	960	890	− 7.3
.107	1180	1090	− 7.6
[1].122	1870	1640	−12.3
.131	2410	2480	+ 2.9
.143	2970	3400	+14.5
150	3610	3310	− 8.3
.155	3480	4050	+16.4
.167	4190	4900	+16.9
.179	4760	5000	+ 5.0
.191	5870	6570	+11.9
.200	7040	7080	+ .6

[1]Mix ratio recommended by Omega Chemical.

Performance: The liquid components and the mixed retardants were tested using standard procedures. The probes were conditioned for 16 hours in the test solution, connected to the Corrater, and the current flow was monitored for 8 hours in the slowly (1 r/min) moving solution. The probes were removed from the test solution, rinsed under gently running warm water, and allowed to air dry. The probes were then reimmersed and another 8-hour dynamic test monitored. The probes were removed again, rinsed (this time under a very hard stream of cold water), and allowed to air dry. A third 8-hour dynamic test was then monitored. The uniform corrosion rates and pitting index were calculated using a minimum of three replications, all results averaged, and the standard error of the mean calculated. The corrosion rates, pitting indices, and standard errors are summarized in table 4.

The uniform corrosion rate of Megatard 2700A was less than 1 mil/yr on 2024-T3 aluminum and less than 5 mils/yr (moderately corrosive) on 1010 steel and naval brass. Megatard 2700B, which uses a different inhibitor, was subsequently formulated and submitted in an attempt to obtain a retardant salt/inhibitor system that would meet the less than 1 mil/yr uniform corrosion requirement on all three of the specified alloys. This formulation change lowered the corrosion rate on naval brass but nearly tripled the corrosion rate for mild steel. This was unexpected in view of the results of screening tests performed by Ocean City Research Corporation (OCRC) under contract to USDA Forest Service (Gehring 1974, 1978) of several retardant salt/inhibitor combinations (tables 5 through 7). Table 5 shows the results of screening tests utilizing polarization resis-

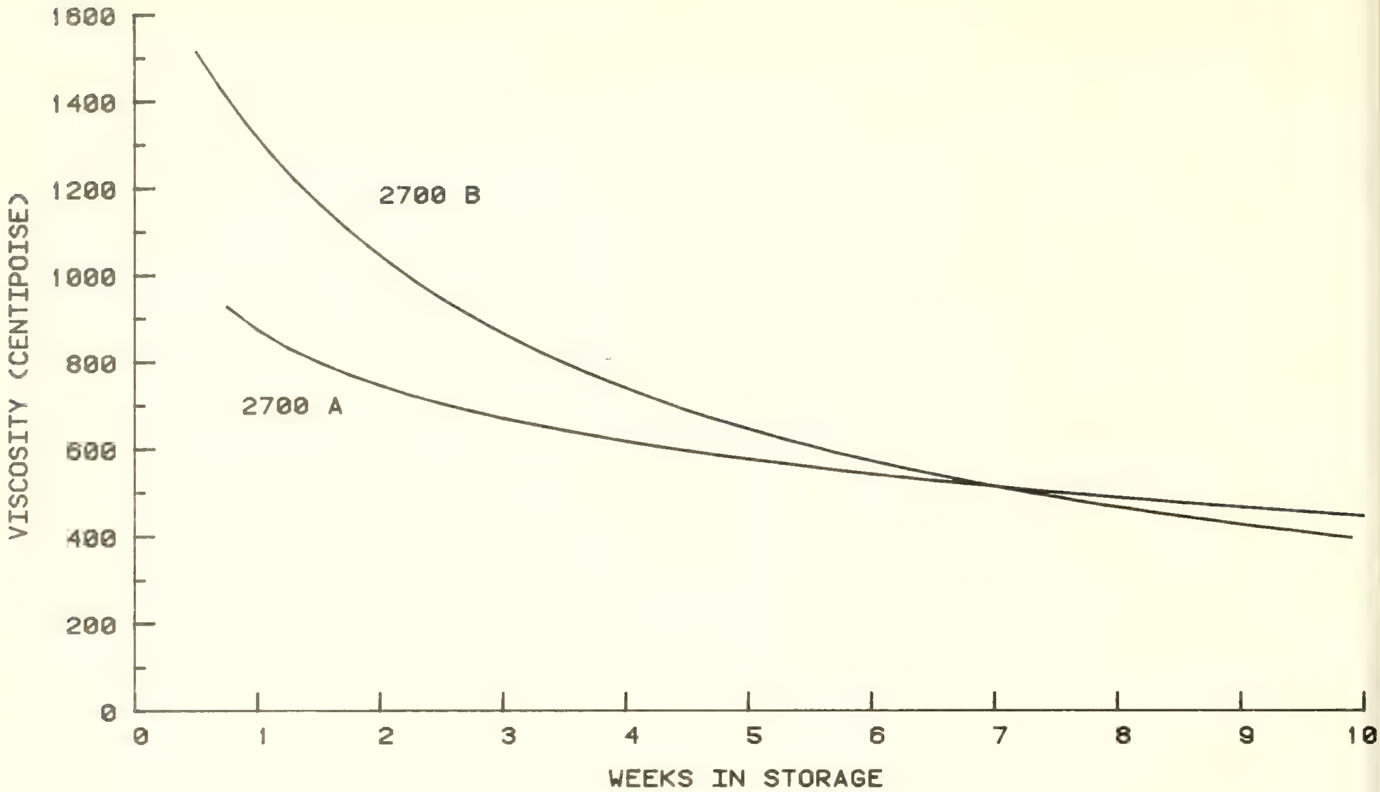


Figure 4.—Viscosity of Megatard 2700A and 2700B during the initial 10-week period (30-day performance shown by a dotted line).

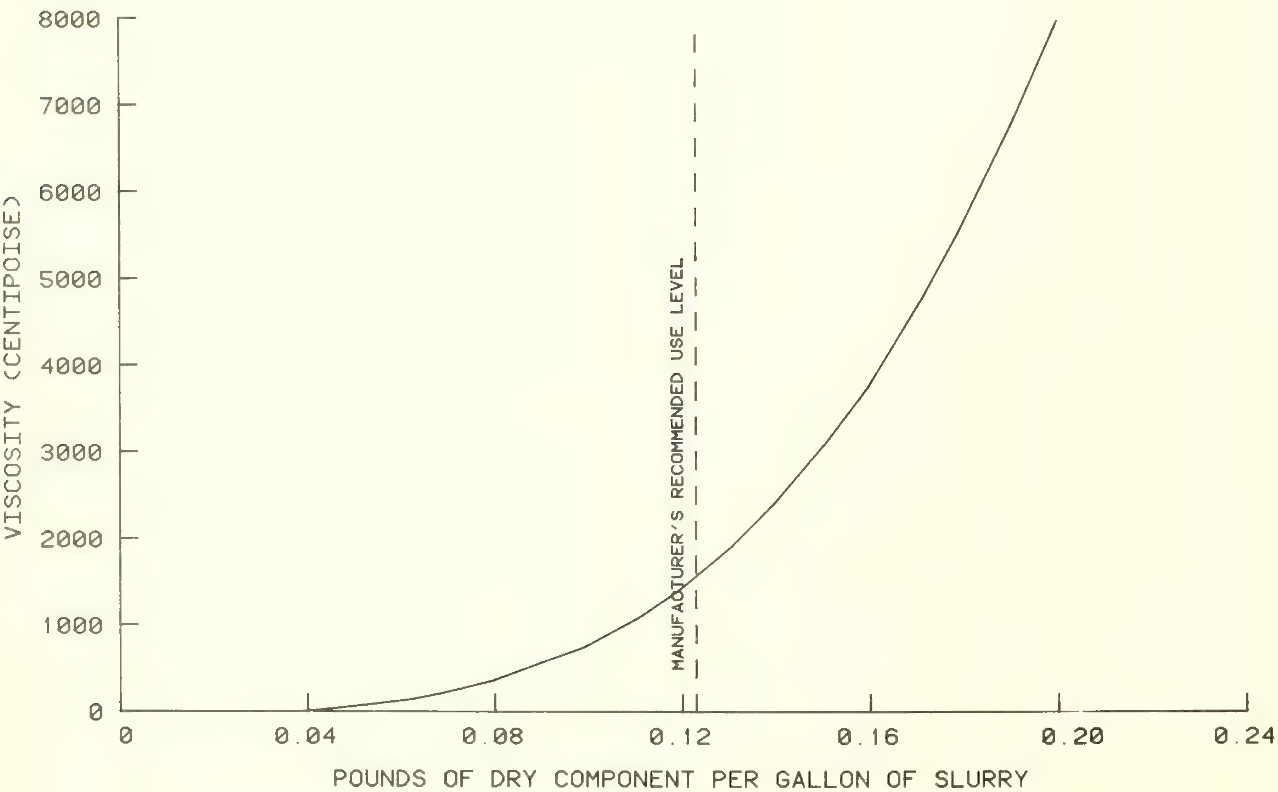


Figure 5.—The effect of changes in thickener concentration on the viscosity of Megatard 2700A.

Table 4.—Results of uniform corrosion testing of Megatard 2700 using the Magna Corrater

	2700A		2700B	
	Liquid component	Mixed retardant	Liquid component	Mixed retardant
	Mils/yr			
MEGATARD 2700A AT BEGINNING OF TEST PERIOD				
2024-T3 Aluminum				
Average uniform corrosion	0.44	0.09	0.26	0.21
Standard deviation	.17	.05	.12	.11
Standard error	.08	.03	.07	.06
Pitting index	.31	.06	.15	2.58
1010 steel				
Average uniform corrosion	5.22	3.90	17.50	10.20
Standard deviation	.19	.43	.76	1.16
Standard error	.10	.25	.44	.67
Pitting index	3.12	2.47	17.70	16.60
Naval brass				
Average uniform corrosion	1.03	2.86	.03	.07
Standard deviation	.49	.16	<.001	06
Standard error	.28	.08	<.001	.03
Pitting index	.17	.73	03	03
MEGATARD 2700A FOLLOWING 1-YEAR OUTDOOR STORAGE - MISSOULA, MONT.				
2024-T3 Aluminum				
Average uniform corrosion	0.08	0.16		
Standard deviation	.02	.06		
Standard error	.02	.04		
Pitting index	.07	.05		
1010 steel				
Average uniform corrosion	6.15	.60		
Standard deviation	.45	.05		
Standard error	.31	.03		
Pitting index	2.60	.33		
Naval brass				
Average uniform corrosion	.44	.07		
Standard deviation	.09	<.01		
Standard error	.06	<.01		
Pitting index	.08	.13		
MEGATARD 2700A FOLLOWING 1-YEAR OUTDOOR STORAGE - SAN DIMAS, CALIF.				
2024-T3 Aluminum				
Average uniform corrosion	0.32	0.19		
Standard deviation	.20	.04		
Standard error	.10	.03		
Pitting index	.08	.20		
1010 steel				
Average uniform corrosion	7.29	1.15		
Standard deviation	.30	04		
Standard error	.20	.03		
Pitting index	3.90	.25		
Naval brass				
Average uniform corrosion	1.85	.46		
Standard deviation	.60	.02		
Standard error	.40	.01		
Pitting index	1.25	.18		

Table 5.—Effectiveness of candidate corrosion inhibitors in ammonium sulfate for common alloys exposed 24 hours (Gehring 1974)[1]

Alloy	2024 Al	2024 AIC	6061 Al	7075 Al	Mg	Naval brass	Galv. 1010	4130 steel	304 SS	410 SS
Inhibitor	Corrosion rate (mils/yr)									
Thiourea	0.921	0.921	0.491	0.356		6.17	23.97	2.19	0.0113	0.051
Dimethylamine	.143	.152	.019	.036		1.08	.477	.971	.080	.065
Ammonium thiocyanate	.065	.224	.098	.179	671.7	.167	2.52	.722	.011	.21
Sodium fluorosilicate	1.98	5.87	3.25	1.35		2.08	48.09	46.4	.0073	1.28
Sodium dichromate	1.11	.917	.042	.089		.78	.20	.125	.040	.032
Ammonium fluoride	.484	1.49	.619	4.31		.294	9.04	.437	.0092	.403
Sodium MBT	.161	.143	.028	.035		.216	.271	.306	.018	.098
Sodium nitrite	.424	.0092	.0024	.169		.177	20.7	19.1	.0069	.69
Aniline sulfate	.167	.0402	.033	.067	0.193	1.17	21.95	.655	.0044	.396
Sodium ferrocyanide	.088	.110	.020	.017		.268	.75	.834	.055	.055

[1]Determined by polarization resistance measurements at 20 C.

Table 6.—General corrosion rates for inhibited ammonium sulfate solutions determined by 30-day exposure weight loss and polarization resistance measurements (Gehring 1978)

Alloy		2024 Al	6061 Al	7075 Al	Mg	Brass	4140 steel	1010 steel
Inhibitor		Corrosion rate (mils/yr)						
Ammonium sulfate[1] without inhibitor	Weight loss[2]	0.381	0.32	0.287	—	1.58	3.35	4.17
	initial[3]	.017	.028	.024	>250	1.08	1.55	.589
	7 days	.0096	.0092	.0086	—	2.98	2.36	1.31
	14 days	.011	.014	.011	—	2.69	3.51	2.06
	21 days	.0081	.0089	.0087	—	2.09	4.05	3.01
	30 days	.0083	.0080	.0089	—	1.68	3.86	3.71
1% sodium nitrite in ammonium sulfate	Weight loss	.369	.247	.284	—	11.6	10.1	4.09
	initial	.053	.052	.115	>500	24.9	.646	.168
	7 days	.021	.019	.014	—	6.88	.616	.026
	14 days	.0035	.056	.0045	—	15.7	1.82	.085
	21 days	.0039	.166	.0057	—	33.6	9.32	6.66
	30 days	.0036	.348	.0041	—	21.5	9.32	9.11
1% sodium ferrocyanide in ammonium sulfate	Weight loss	.155	.113	.092	—	<.001	.452	.378
	initial	3.65	2.27	2.71	>250	.125	.549	.926
	7 days	.048	.034	.073	—	.059	.652	.775
	14 days	.0098	.0073	.010	—	.053	.664	.870
	21 days	.0056	.0045	0053	—	.057	1.25	.799
	30 days	.0028	.0029	.0034	—	.080	2.28	.975
1% dimethylamine in ammonium sulfate	Weight loss	.207	.137	.101	—	1.72	2.21	4.28
	initial	.595	.852	1.17	>250	.025	.566	.728
	7 days	.0075	.0082	0094	—	3.18	.566	1.95
	14 days	.0045	.0065	.008	—	3.10	.657	2.76
	21 days	.0036	.0044	.007	—	3.44	.657	1.76
	30 days	.0036	.0045	.0065	—	3.50	1.87	1.66
1% sodium MBT in ammonium sulfate	Weight loss	.195	.107	.107	—	.814	1.03	2.52
	initial	3.01	1.10	1.64	>500	.051	.361	.561
	7 days	.013	.0089	.017	—	.936	.461	.536
	14 days	.0095	.010	.010	—	1.21	.617	.677
	21 days	.0088	.009	.009	—	1.20	.472	.728
	30 days	.0058	.0065	.008	—	1.15	.510	.765

[1]15 percent solution, by weight, 20 C.
[2]Corrosion rate determined by weight loss over 30-day period.
[3]Corrosion rates initially and at 7, 14, 21, and 30 days determined by polarization resistance measurement.

Table 7.—General corrosion rates for sodium ferrocyanide inhibited ammonium sulfate determined under 90-day total and partial immersion conditions (Gehring 1978)

Retardant/inhibitor →		Ammonium sulfate/1% $Na_4Fe(CN)_6$			
Immersion condition →		Partial		Total	
Alloy		Sample 1	Sample 2	Sample 3	Sample 4
2024 Aluminum	CR (initial)[1]	0.059	0.093	0.037	0.017
	CR (final)[2]	.047	—	.043	.059
	CR (weight loss)[3]	.076	.085	.065	.132
	Max. pit depth[4]	1.31	8.61	[6]—	4.72
Brass	CR (initial)	.258	.618	—	.162
	CR (final)	57.3	43.9	—	.319
	CR (weight loss)	20.2	32.3	—	.102
	Max. pit depth	[5]—	[5]—	—	—
4140 steel	CR (initial)	28.0	119	18.7	27.3
	CR (final)	—	82.0	39.7	40.9
	CR (weight loss)	17.1	23.1	11.3	14.0
	Max. pit depth	6.96	14.8	—	—

[1]Corrosion rate (MPY) determined initially by polarization resistance measurement.
[2]Corrosion rate (MPY) determined at 90 days by polarization resistance measurements.
[3]Corrosion rate (MPY) determined by weight loss after 90 days.
[4]Expressed in milli-inches.
[5]Coupons exhibited ≃ 30-50 percent reduction in thickness at vapor/liquid interface.
[6]Samples with no maximum pit depth given were uniformly corroded over entire surface

tance measurements after exposure to the solution for 24 hours. Table 6 shows results of weight loss tests for some of the same combinations after 30 days of exposure as well as polarization resistance measurements at 7-day intervals through the 30-day test period. Table 7 shows the results of weight loss and polarization resistance measurements for sodium ferrocyanide in ammonium sulfate over a 90-day interval and includes partial as well as total immersion conditions.

Several factors must be considered when comparing these test results. Corrosion rates vary with the test procedure used, the test conditions (temperature, exposure, etc.), and the length of exposure to the test solution. The results in table 4 were obtained using the Magna Corrater (linear polarization) during a 3-day time period with 40 hours of actual exposure. During this time the probes were removed from the solution twice and then rinsed and allowed to dry before continuing the test. Depending on the mechanism of inhibition, this procedure might cause a breakdown or fracture of the inhibitor film protecting the probe. At the same time, the movement of the solution over the probes might cause the film to form differently than in a still solution, or not at all. The polarization resistance procedure was performed at varying time intervals up to 90 days. During this time the solution was not agitated and probes remained immersed in the test solution for the entire test period. This might allow a more stable inhibitor film to form (especially over the longer time periods), and the film would be less likely to be disturbed once it was formed. Gehring (1978) concluded after performing the tests summarized in tables 5 and 6 that the extremely short duration (24 hours) of the screening test did not necessarily reflect long-term performance. Weight loss tests were performed at the end of the test period on the same coupons that underwent the polarization resistance tests so that the same factors would apply. In addition, weight loss test results are an average of the actual loss of metal due to electrochemical activity over the entire test period.

Gehring (1978) also utilized 90-day total and partial immersion weight loss tests in investigating the effect of a 1 percent sodium ferrocyanide inhibited ammonium sulfate solution (see table 7). The partial immersion exposure is usually a more severe test condition in that it includes the possibility for increased electrochemical activity at the liquid/vapor interface. Gehring (1974) well documented that this condition typically occurs at airtanker bases where retardant is mixed and transferred into storage and/or aircraft for use. A retardant can yield total immersion corrosion rates of less than 1 mil/yr while exhibiting high corrosion rates under partial immersion conditions and during operational use. During laboratory partial immersion tests it is not uncommon to have corrosion extending almost through the entire thickness of a coupon while leaving the two halves nearly untouched. This is demonstrated in the data in table 7 for both brass and steel.

After reviewing results of the earlier corrosion tests, several modifications to the formulas were made in an attempt to reduce the corrosion rate on the mild steel and brass alloys used in the evaluation. Since ortho phosphate is commonly used to inhibit corrosion of mild steel in neutral and basic aqueous solutions (Nathan 1973; Uhlig 1971), diammonium phosphate was added

Table 8.—Uniform corrosion rates of Megatard 2700A and 2700B compared to the corrosion rates for several modified Megatard solutions

Sample	Inhibitors	Alloy	Uniform corrosion	Standard deviation	Standard error	Pitting index
			Mils/yr			
		MEGATARD 2700A				
	1% NH_4SCN	2024-T3 aluminum	0.09	0.05	0.03	0.05
		1010 steel	3.90	.43	.25	2.47
		Naval brass	2.86	.16	.08	.73
		MEGATARD 2700B				
	1% $Na_4Fe(CN)_6$	2024-T3 aluminum	.21	.11	.06	2.58
		1010 steel	10.20	1.16	.67	16.60
		Naval brass	.07	.06	.03	.03
		MODIFIED FORMULATIONS OF MEGATARD 2700				
Sample 1	1% NH_4SCN	2024-T3 aluminum	.23	<.01	<.01	.25
	1% $(NH_4)_2HPO_4$	1010 steel	1.57	.02	.01	.28
		Naval brass	2.41	.08	.05	.20
Sample 2	1% NH_4SCN	2024-T3 aluminum	.22	<.01	<.01	.45
	2% $(NH_4)_2HPO_4$	1010 steel	.74	.07	.05	2.60
		Naval brass	2.00	.22	.16	.15
Sample 3	0.5% NH_4SCN	2024-T3 aluminum	.61	.43	.30	.80
	0.5% $Na_4Fe(CN)_6$	1010 steel	3.96	.11	.08	2.10
		Naval brass	.08	<.01	<.01	.07
Sample 4	1% NH_4SCN	2024-T3 aluminum	.21	.10	.05	.96
	1% $Na_4Fe(CN)_6$	1010 steel	2.98	.58	.29	.85
		Naval brass	.23	.05	.03	.08
Sample 5	1% $Na_4Fe(CN)_6$	2024-T3 aluminum	.37	.16	.09	.22
	2% $(NH_4)_2HPO_4$	1010 steel	1.47	1.05	.61	7.70
		Naval brass	.13	<.01	<.01	.10
Sample 6	0.5% $Na_4Fe(CN)_6$	2024-T3 aluminum	.51	<.01	<.01	.21
	2% $(NH_4)_2HPO_4$	1010 steel	6.56	2.60	1.30	16.1
		Naval brass	.209	.02	.01	.69
Sample 7	0.5% NH_4SCN	2024-T3 aluminum	.29	.08	.06	.58
	0.5% $Na_4Fe(CN)_6$	1010 steel	1.02	.02	.01	1.20
	2% $(NH_4)_2HPO_4$	Naval brass	.49	.05	.04	.16

to several Megatard 2700 samples. Sample 1 was formulated to provide a retardant having a salt concentration of 14 percent ammonium sulfate and 1 percent diammonium phosphate in addition to the 1 percent ammonium thiocyanate. Sample 2 was similarly prepared to yield 13 percent ammonium sulfate, 2 percent diammonium phosphate, and 1 percent ammonium thiocyanate. Standard Corrater tests were then run in the manner described earlier. The results were as expected (the results of these and tests to be discussed are given in table 8). The corrosion rates on mild steel were significantly decreased with the addition and increase in concentration of ortho phosphate. These formulation changes also resulted in a slight decrease in the corrosion rate of brass.

In a further attempt to obtain lower corrosion rates for naval brass, a sample was prepared containing a combination of the corrosion inhibitors used in the Megatard 2700A and 2700B formulation (sample 3). In this sample, the final inhibitor concentration was 0.5 percent ammonium thiocyanate and 0.5 percent sodium ferrocyanide. An additional sample (sample 4) with the same two inhibitors each adjusted to 1 percent was also tested. Both samples yielded a corrosion rate of less than 1 mil/yr on brass. The corrosion rate of 1010 steel, however, was 3.96 and 2.98 for the two samples, significantly higher than the rates obtained when a 1 or 2 percent diammonium phosphate was used as an inhibitor.

Diammonium phosphate at 2 percent was added to Megatard formulations containing 0.5 and 1 percent sodium ferrocyanide and tested (samples 5 and 6). Sample 5 containing 0.5 percent sodium ferrocyanide and 2 percent diammonium phosphate caused only a slight improvement in corrosion inhibition over standard Megatard 2700B. The sample containing 1 percent sodium ferrocyanide and 2 percent diammonium phosphate resulted in a significant improvement. The corrosion rate for steel decreased from 10.2 to 1.47 mils/yr, while the corrosion rates on aluminum and brass increased slightly but were still well below the 1 mil/yr requirement.

Finally, a sample was formulated with 2 percent diammonium phosphate and 0.5 percent ammonium thiocyanate and 0.5 percent sodium ferrocyanide and tested (sample 7). This inhibitor system lowered the corrosion level on mild steel to approximately 1 mil/yr, while maintaining low corrosion rates for aluminum and brass.

The results of these additional tests suggest that a combination of Megatard 2700 inhibitors with diammonium phosphate is preferable to a single inhibitor for the proposed gum-thickened ammonium sulfate system.

New corrosion requirements were proposed in January 1979, for inclusion in USDA Forest Service specifications for forest fire retardants. The proposed test procedure included 90-day weight loss tests under both total and partial immersion conditions at 70° and 120° F. The proposed requirement provided a maximum allowable corrosion rate after 90 days of 2 mils/yr for total immersion conditions and 70° F partial immersion conditions, and 5 mils/yr for 120° F partial immersion conditions. Incorporation of this test will likely occur following verification of the requirements utilizing existing approved retardant formulations. Final requirements will likely be set as to eliminate formulations having higher corrosion rates than those currently approved and in use.

Megatard 2700A and 2700B were tested according to the proposed procedures and the results are shown in table 9. Table 9 also includes the performance of Fire-Trol 100™, which was included in the test for comparison purposes as an approved ammonium sulfate based fire retardant. The results of the total immersion weight loss tests confirmed the ability of the 1 percent solution of ammonium thiocyanate or sodium ferrocyanide to inhibit corrosion to aluminum. Both inhibitors were effective in reducing corrosion to brass and steel; however, at the elevated temperatures the corrosion rate for the sodium ferrocyanide formulation was significantly higher for steel (1.97 mils/yr as compared to 0.56 mil/yr; allowable under the proposed weight loss procedure is 2 mils/yr).

Table 9.—Results of 90-day weight loss tests performed on Megatard 2700A, Megatard 2700B, and Fire-Trol 100

	Megatard 2700A	Megatard 2700B	Fire-Trol 100
	Mils/yr		
Total - 70° F			
2024-T3 aluminum	<0.001	<0.001	<0.001
4130 steel	.119	.265	.051
Yellow brass	.068	.001	.016
Az-31-B magnesium	>100.	>100.	>100.
Total - 120° F			
2024-T3 aluminum	.184	<.001	.002
4130 steel	.562	1.97	.083
Yellow brass	.133	<.001	.006
Az-31-B magnesium	>100.	>100.	>100.
Partial - 70° F			
2024-T3 aluminum	<.001	<.001	<.001
4130 steel	3.90	1.13	2.65
Yellow brass	.057	5.41	6.14
Az-31-B magnesium	>100.	91.3	51.4
Partial - 120° F			
2024-T3 aluminum	.483	.034	.026
4130 steel	13.2	9.92	6.53
Yellow brass	259	.083	31.6
Az-31-B magnesium	>100.	>100.	>100.

Results of all partial immersion tests gave a less than 1 mil/yr corrosion rate for aluminum. Results for steel and brass were less consistent; both Megatard 2700B and Fire-trol 100 gave corrosion rates of greater than 5 mils/yr for brass (5.4 and 6.1 respectively) while rates for mild steel were between 1 and 4 mils/yr (Fire-Trol 100 corrosion rates falling between those for Megatard 2700A and 2700B; the proposed requirement was 2 mils/yr). At the higher temperature (120° F) all three formulations exceeded 5 mils/yr on steel.

Weight loss tests under all conditions indicated catastrophic corrosion to magnesium when exposed to any of the three formulations.

The advantages of combining inhibitors and/or adding diammonium phosphate were not investigated using any of the weight loss procedures.

We sent the aluminum test coupons used for the weight loss tests on Megatard 2700A and 2700B to Ocean City Research Corporation for sectioning and microscopic examination for intergranular corrosion. None of the coupons showed signs of intergranular corrosion. Limited pitting on several of the coupons occurred, however, when exposed to partial immersion conditions.[5] This confirms results obtained by the San Dimas Equipment Development Center, which had examined aluminum, brass, and steel Corrater probes for intergranular corrosion after exposure for 8 days to samples of Megatard 2700A taken from both the top and bottom segments of the samples stored outdoors at Missoula (discussed in the section on storage).[6]

Although corrosion fatigue tests were not required nor conducted, related test results are of interest and should be considered. Ocean City Research Corporation (Gehring 1978) conducted fatigue testing that indicated sodium ferrocyanide in ammonium sulfate

[5]Memorandum from George Gehring to Charles George dated September 9, 1979, regarding USDA Forest Service Purchase Order #43-0353-9-698, Metallurgical Inspection Services. Memorandum and accompanying data on file at Northern Forest Fire Laboratory.

[6]Laboratory report by Peabody Testing Services, Division of Magnaflux Corporation, Los Angeles, Calif., to USDA Forest Service Equipment Development Center. Metallurgical data on file at the Northern Forest Fire Laboratory.

solutions increased the fatigue life of 2024-T3 aluminum as compared to uninhibited ammonium sulfate. Additional fatigue studies are under way; however, no fatigue testing has been performed on either the complete Megatard 2700A or 2700B formulation.

pH Value

Dry and Liquid Chemical Requirement (301, 302): When the liquid concentrate and "mixed retardant" are tested using a full-range pH meter having a sensitivity of at least ±0.1 pH units, the pH value shall be between 5.5 and 8.0.

Performance: The pH of the Megatard liquid components and "mixed retardants" are within the required range:

	pH values	
	Beginning of test period	After 1-year storage
Megatard 2700A liquid component	5.5	5.3
Megatard 2700A mixed retardant	6.9	6.7
Megatard 2700B liquid component	6.3	—
Megatard 2700B mixed retardant	6.9	—

Combustion Retarding Effectiveness

Dry and Liquid Chemical Requirement (301, 302): When the "mixed retardant" is applied to ponderosa pine needle and aspen excelsior fuel beds, allowed to dry, and the beds burned, the combined reductions in rate of spread and intensity shall yield a superiority factor between 0.6 and 1.0 ($\pm S_m$).

Performance: An actual effectiveness evaluation was not performed since the Megatard 2700 products were formulated with a standard fertilizer grade ammonium sulfate (100 percent water soluble) for which considerable data are available (George and Blakely 1972). The results of the earlier tests have not indicated significant differences in the effectiveness of fertilizer grade ammonium sulfates (as opposed to the significant effect of purity of ammonium polyphosphate fertilizers). We made an analysis of trace elements in the ammonium sulfate provided as a component of the Megatard 2700 formulation. This documented the quality of ammonium sulfate being used throughout the evaluation and for possible future comparisons. The trace elements in Megatard 2700A retardant component (part 1) mixed to 15.6 percent ammonium sulfate (component 1 contains ammonium thiocyanate) were:[7]

Zinc	0.6 ppm	Nickel	0.1 ppm
Iron	4 ppm	Chromium	0.2 ppm
Manganese	1 ppm	Lead	1.1 ppm
Copper	7 ppm	Cadmium	<0.1 ppm
Magnesium	38 ppm	Fluoride	0.93 ppm
Calcium	400 ppm	Chloride	1300 ppm

Table 10.—Summary of factors included in rating combustion retarding effectiveness

	1 GPC[1]	2 GPC
Grams ammonium sulfate/ft^2	6.17	12.34
Reduction in rate of spread (percent)		
Ponderosa pine needles	37	66
Aspen excelsior	70	81
Reduction in rate of weight loss (percent)		
Ponderosa pine needles	37	47
Aspen excelsior	51	60
Superiority factor	0.49 ± .04	0.64 ± .03
Overall superiority factor	0.57 ± .03	

[1]GPC is gallons per 100 ft^2.

Although no burn tests were conducted, a "paper analysis" of the performance levels of ammonium sulfate as a fire retardant was undertaken. Data points were generated, plotted, and compared to standard ammonium sulfate effectiveness curves using equations for reduction in rate of spread, reduction in intensity, and superiority factors previously developed (George and Blakely 1972), and the concentration of ammonium sulfate present in the mixed Megatard samples. A summary of the data is given in table 10 and relationships shown in figures 6 and 7. The effectiveness of the formulations at application rates of 1 and 2 gal/100 ft^2 (GPC) are shown by the points plotted on the standard curves. All points fell near the standard curve. The overall superiority factor of 0.57 ± 0.03 for a 15 percent ammonium sulfate solution indicates acceptable performance; however, a slight reduction in the salt content would result in inadequate ammonium sulfate to obtain the required performance as per present specifications.

Based on previous evaluations, the effect of the addition of the gum-thickener to the ammonium sulfate is not expected to significantly alter the combustion-retarding effectiveness of the mixed retardant. Alterations in the formulation as were made in the corrosion section would not be expected to significantly alter the effectiveness of the overall product. In fact, substitution of 1 percent diammonium phosphate for 1 percent ammonium sulfate as a corrosion inhibitor should increase the combustion retarding ability of the formulation provided a high grade (white-acid) ammonium phosphate is used.

[7]Analysis performed by A & L Agricultural Laboratories, Memphis, Tenn., 1977. Analysis report on file at the Northern Forest Fire Laboratory.

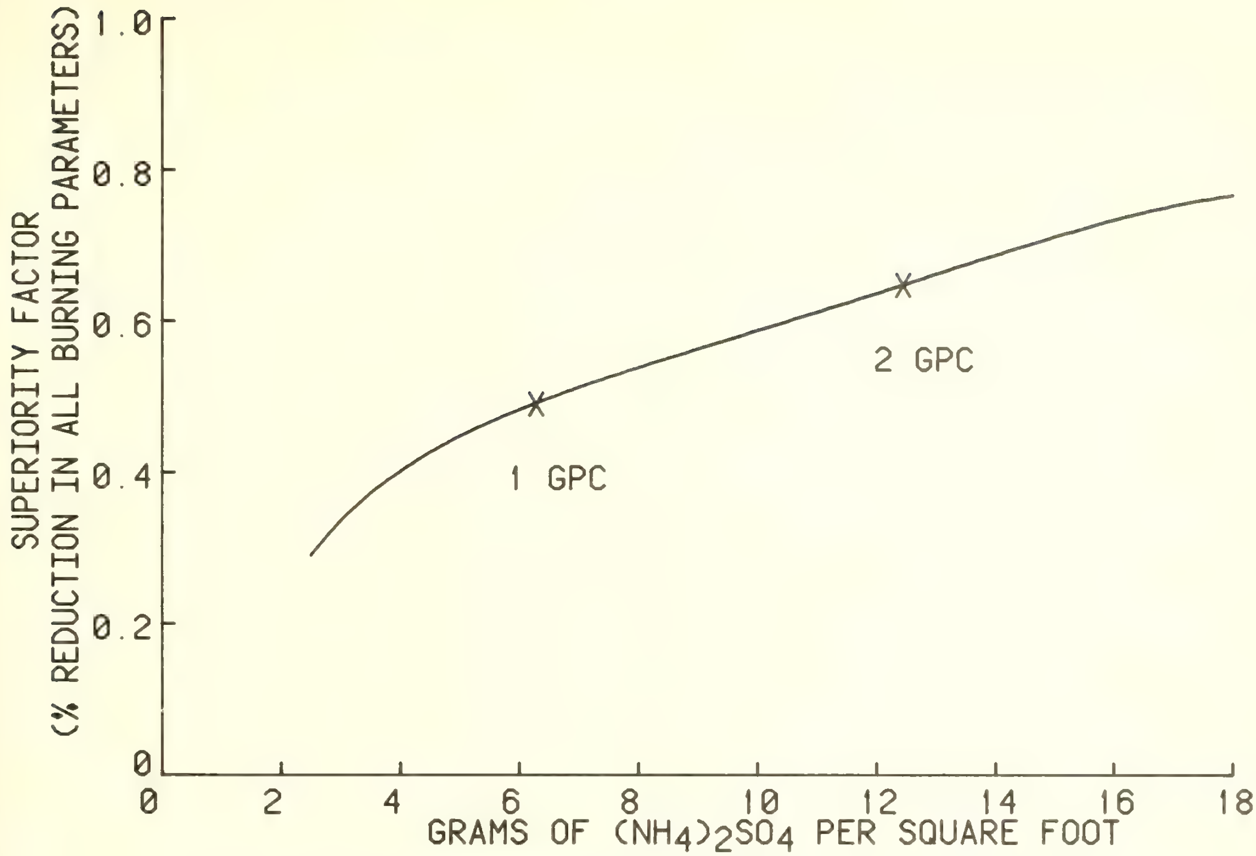


Figure 6.—Estimate of the superiority factor of Megatard 2700 products formulated with ammonium sulfate (AS)

olor

Dry Chemical Requirement (301): The "mixed re-ırdant" shall contain a nonstaining coloring agent in ıe following proportions of iron oxide, or equal:

Retardant	Gms/gal "mixed retardant"
Type A Class II	4
Type A Class III	10

Dry Chemical Requirement–(Amendment): Visi-lity when tested. When the "mixed retardant" is drop-ed onto brush and timber fuel types, experienced bservers, in a following light aircraft, shall determine if sibility of the product is acceptable.

Liquid Chemical Requirement (302): Type A liquid ncentrate shall contain sufficient nonstaining color-g agent so that the "mixed retardant" shall contain a inimum of 16 grams of coloring agent Fe_2O_3 per mixed allon or equal.

Liquid Chemical Requirement–(Amendment): pacity. When the "mixed retardant" is tested in ac-ordance with a specific opacity test (4.3.1.5.1.) the aximum amount of transmitted light shall not exceed ı illuminance of 36 lux.

Performance: Properly mixed Megatard 2700 con-ins 10.25 grams of iron oxide per gallon. This exceeds e limits set for the dry retardants but does not meet the requirements for liquids. No visibility problems exist using presently approved dry-chemical-based retardants (meeting above color requirements). The level of iron oxide in Megatard 2700 should therefore be adequate.

Amendments to Forest Service Specifications 5100-00301a and 5100-00302b include requirements for visibility and opacity that may be evaluated during testing at San Dimas Equipment Development Center or during an operational evaluation.

Mixing

Dry Chemical Requirement (301): Each retardant will be mixed under specified conditions to determine the retardant expansion and the net horsepower required to mix 1 gallon of retardant.

Liquid Chemical Requirement (302): Mixing shall be limited to pumping proportional volumes of the concentrate and water together.

Performance: The Megatard 2700 system uses components requiring low shear to make a thickened retardant (simple blenders or powder eductors). The dry component is injected into a water stream producing thickened water. The liquified thickener is then pumped together with the liquid ammonium sulfate component forming a thickened slurry that can be loaded directly into an airtanker. No further agitation is required.

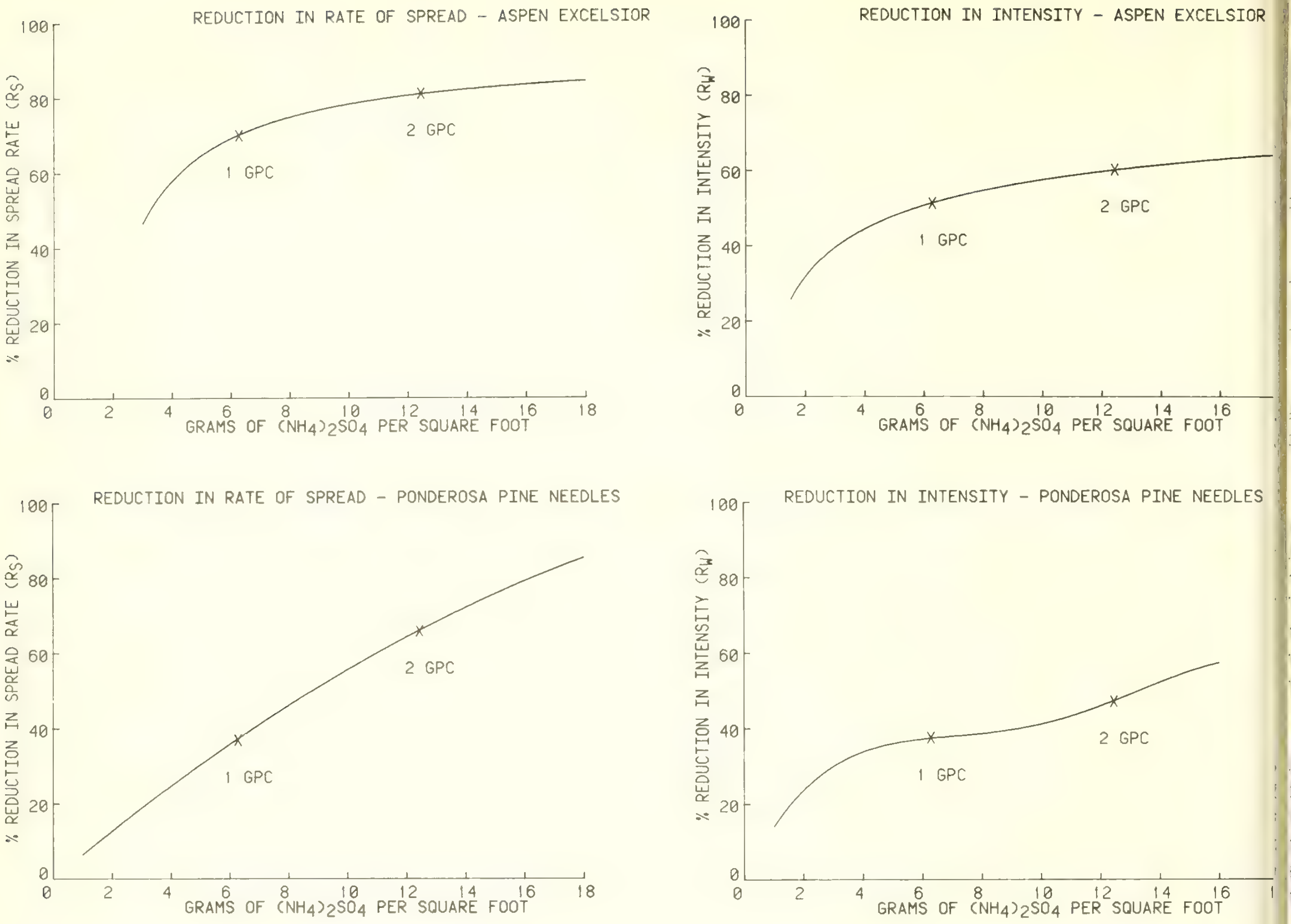


Figure 7.—Relationships used in determining the superiority factor of Megatard 2700 products formulated with ammonium sulfate.

Mixing several batches of Megatard 2700 for use in other tests has suggested that the amount of shear is responsible for much of the variation in viscosity between samples. To confirm this, samples of Megatard 2700 and of Phos-Chek XA (a thickened product that uses a similar gum as the thickening agent) were mixed using a simple laboratory stirrer and a Waring blender for varying amounts of mixing time to alter the amount of shear to the sample. Samples of Megatard 2700A and Phos-Chek XA (a currently approved gum-thickened retardant) were mixed for 3 minutes using the Waring blender, and the viscosities measured at 1, 2, 3, 4, and 5 minutes and at 5-minute intervals thereafter for 60 minutes. Allowing for variations in measurements due to extreme aeration (common in laboratory blended samples) during the first 15 minutes, both samples reached and maintained acceptable viscosities during mixing. Similar results were found when samples were mixed with the laboratory stirrer for 5 minutes. After waiting for 1 hour to allow entrapped air to escape, the viscosities were measured. Results are shown in table 11. Although different amounts of shear were required, generally similar results were obtained with both retardants. There appears to be a definite minimum shear (which differs with the gum being used) required to obtain adequate viscosity, and an optimum shear to provide the best solution stability. The effect of shear during blending should be a major design input when field equipment is developed. If adequate blending is given originally, the rate of hydration is not a limiting factor; in other words, near maximum viscosities can be attained during mixing and prior to filling the airtanker.

Further testing by San Dimas Equipment Development Center may be conducted if it is necessary to determine the horsepower required to mix a gallon of retardant. The test is normally required for retardants mixed in conventional batch mixers.

Salt Content

Dry Chemical Requirement (301): When chemically analyzed the salt content of the "mixed retardant" will be at least:

Retardant	Percent solution by weight
Type A Class II (gum-thickened)	10.0% $(NH_4)_2HPO_4$
Type A Class III (clay-thickened)	15.0% $(NH_4)_2SO_4$

Liquid Chemical Requirement (302): When the quid concentrate is chemically analyzed, the salt con-ent shall not be less than 30 percent P_2O_5 equivalent. \fter the liquid concentrate has been stored outside for year, the sample shall again be analyzed. The salt ontent shall be within that obtained before storage by lus or minus 3 percent.

Performance: Megatard 2700 is a dry, gum-thick-ned, ammonium sulfate-based retardant that does not t under the liquid chemical requirement or either type r class of dry chemical requirement.

The liquid chemical requirement contains a minimum cceptable salt content for the liquid concentrate of 30 ercent P_2O_5 which is not applicable.

Although no requirement for an ammonium sulfate oncentrate exists, the 28 percent ammonium sulfate tilized in the Megatard 2700 system is a consideration determining retardant base storage requirements. here is no technical reason, however, that a gum-iickened ammonium sulfate-based formulation could ot meet all performance requirements and operational eeds.

The salt content of all Megatard 2700A and 2700B amples was determined by micro Kjeldahl analysis listillation of ammonia into a boric acid solution and tration of the solution with hydrochloric acid). At least ree replicates of each sample were analyzed and esults averaged. The results of the chemical analysis dicate that salt content requirements are met:

	Salt content	
	Beginning of test period	After 1-year storage
	$\%(NH_4)_2SO_4$	$\%(NH_4)_2SO_4$
legatard 2700A liquid component	30.65	28.08
legatard 2700A mixed retardant	15.06	14.29
legatard 2700B liquid component	25.43	—
legatard 2700B mixed retardant	15.51	—

Calculation of ammonium sulfate from the determina-on of ammonia in fire retardants is a common practice; owever, the accuracy of the results is dependent upon ne purity of the solution. If there is ammonia present at is not in the form of ammonium sulfate ($(NH_4)_2SO_4$), ne results will be erroneously high since all available mmonia will be distilled and included in the calcula-ons that are based on all ammonia and all sulfate being ed together in the desired form.

There is a method for the determination of sulfate in lear, nonturbid, dilute solutions. The sulfate reacts with arium to yield a precipitate of barium sulfate. The mount of precipitate can then be determined from the mount of light absorbed during passage through the sample. For this method to be applied to fire retardants requires the conversion of a highly colored, opaque slurry to a clear, transparent solution without loss of the sulfate ion. It also requires dilution to the appropriate concentration range, and the performance of the standard analysis precipitation and measurement. As with all multistage determinations the number of possible interferences and inaccuracies increases with the number of steps performed, so that the final result may not be more accurate than the simpler, indirect determination of ammonia.

Table 11.—Effect of shear on viscosities obtained for Megatard 2700A and Phos-Chek XA

	Viscosity	
	Megatard 2700A	Phos-Chek XA
	Centipoise	
Mixed using blender: (Waring, low speed)		
Blended for		
0.5 minutes	1010	1800
2.5 minutes	1170	1100
5.0 minutes	1250	840
10.0 minutes	930	410
Mixed using laboratory stirrer: (Precision Scientific, 1750 r/min)		
Blended for		
5.0 minutes	1230	1850

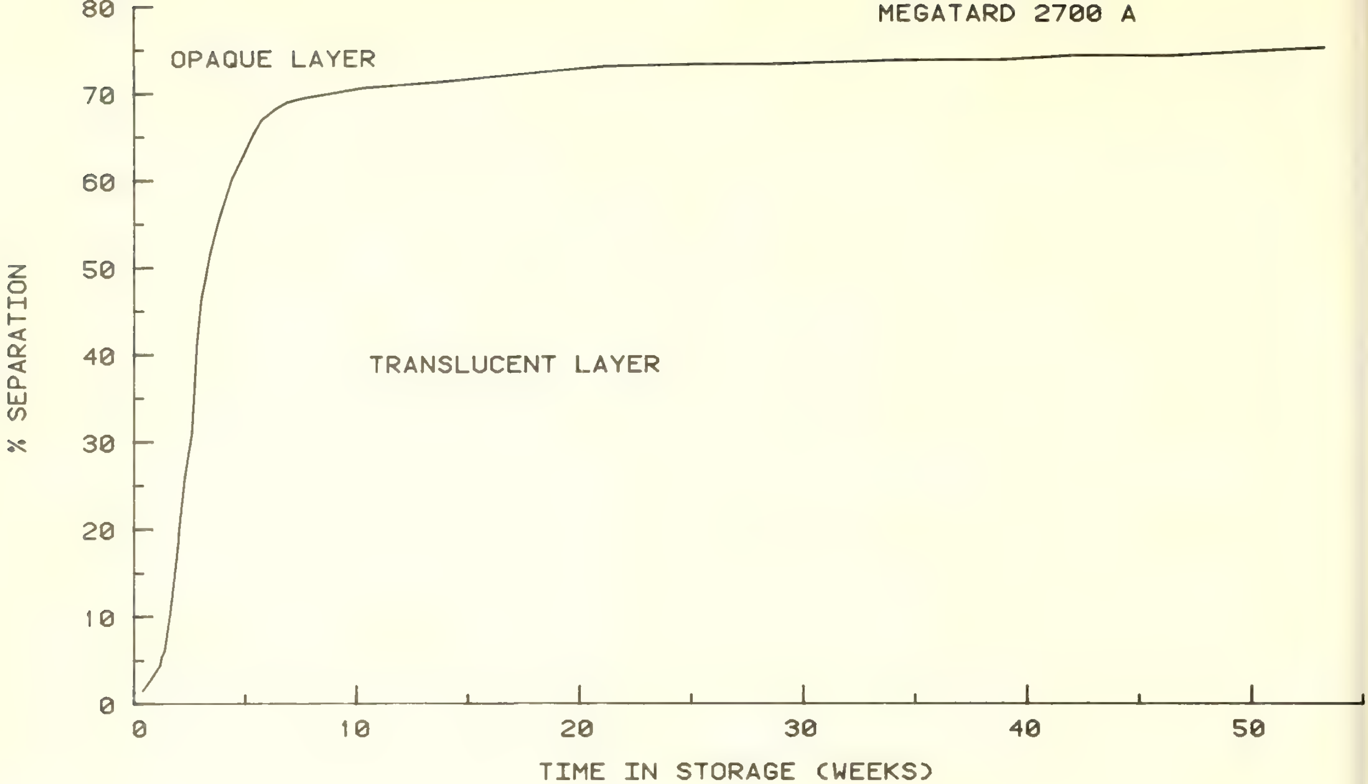
Separation

Dry and Liquid Chemical Requirement for Aircraft Application (301, 302): When the "mixed retardant" is stored undisturbed in loosely covered glass containers for 1 year, there shall be no visual division of one or more components amounting to more than 5 percent by volume.

If separation of the mixed retardant amounting to more than 5 percent occurs, the separation shall not affect the performance of the retardant. This shall be evaluated by collecting specimens from the top, middle, and bottom one-third of the separated stored products, and retesting against the original requirements as appropriate.

Performance: Two samples of each retardant were placed in loosely covered glass jars. One sample contained a steel coupon, as was discussed in the section on viscosity. All samples were checked daily for the first week and weekly for the remainder of the year. Any separation in the column of retardant was measured, and compared to the total retardant height to obtain percent separation.

The liquid component showed no separation after 4 hours and less than 5 percent separation over the entire



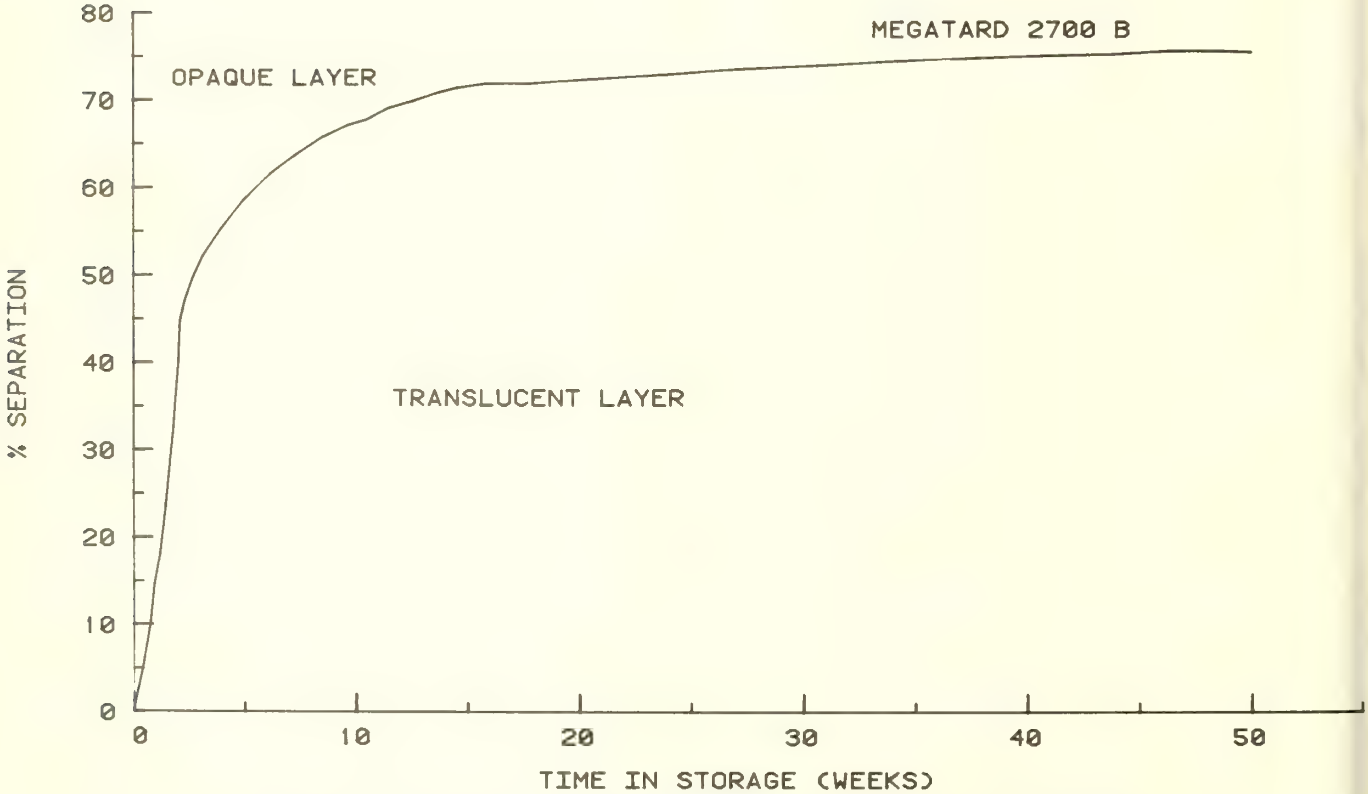


Figure 8.—The effect of storage time on the visual separation of mixed Megatard 2700 retardant.

year. The separation appeared to consist of part of the corrosion inhibitor coming out of solution.

The mixed retardant showed no separation at 4 hours; however, by 30 days about 35 percent separation had taken place in both the 2700A and the 2700B. At the end of 1 year the Megatard 2700A had a very viscous, opaque lower layer, which amounted to about 25 percent of the total volume. A watery, clear, upper layer accounted for 10 percent of the volume, with the center portion (about 65 percent of volume) being translucent but still viscous. After 1 year the Megatard 2700B was about 30 percent separated with a more viscous lower level; the remaining sample graded to a translucent, less viscous material. Figure 8 shows the effect of storage time on separation of Megatard 2700A and 2700B. The performance of the separated components tested is included in the appropriate sections of this report.

Spoilage

Dry and Liquid Chemical Requirement (301, 302): The liquid concentrate and the "mixed retardant" will be placed in glass jars, insulted with 25 ml of Aerobacter bacteria, loosely covered, and allowed to stand undisturbed for 3 months. The samples will be visually observed and the viscosity determined during the test period. Marked separation greater than seen in the separation test, a decrease in viscosity, unpleasant odor, or mold growths will be considered as spoilage.

Performance: Preliminary tests were performed to determine the ability of the retardant samples to support bacterial growth. There was no visible sign of bacterial growth nor the musty smell that often accompanies spoilage. Additional spoilage testing may be deemed necessary and performed by San Dimas Equipment Development Center.

Air Drop Characteristics

Dry and Liquid Chemical Requirement (301, 302): At the option of the Government, the aircraft application type "mixed retardant" will be tested for air drop characteristics under standard conditions from B-17 number 22 or similar aircraft. The "mixed retardant" shall demonstrate a capability of producing ground pattern lengths and total recovery equal to or greater than 95 percent of the values produced by the standard retardant (water) as given below:

Drop parameter	Drop height (ft)		
	150	300	375
Total percent recovery	60	55	50
Length of line (length in feet > 1 gal/100 ft^2)	200	175	150

Performance: Drop tests were not conducted since, based on data previously collected (George and Blakely 1973; George 1975), gum-thickened retardants such as Megatard 2700 can unquestionably be expected to perform better than the standard retardant (water).

An estimate of the drop performance of Megatard 2700 can be obtained by referring to the performance of "gum-thickened" retardants given in the Airtanker Performance Guides[8] for B-17 tanker number 22.

DISCUSSION AND RECOMMENDATIONS

The performances of two fire retardant formulations, Megatard 2700A and 2700B, were quantified in relation to requirements set forth in USDA Forest Service specifications. Since present specifications are for fire retardants mixed using either all "dry" or all "liquid" components, and since there are inconsistencies in the requirements depending on the method of mixing, handling, use, or for other reasons, no single specification was applicable. Thus, the approach was to consider the requirement for both liquid and dry chemical retardants, the rationale for the requirement, and then attempt to quantify the performance in comparable terms. Also used to provide guidance in the evaluation was a proposed single specification recently developed for either liquid or dry fire retardant (USDA Forest Service Specification 5100-00303, proposed 1977), as well as results of ongoing research programs.

The Megatard 2700 system was proposed as a demand mixed system (retardant transferred from component storage, proportioned, and loaded directly onto the aircraft). One-year storage may not be a necessary requirement if storage of the mixed retardant is not an integral part of the system. In this case, the required storage period should be determined by the need and expected operational storage period (the time between retardant proportioning and use). This time will vary with the fire seasons, areas of use, values, and other factors determining operational requirements. George and others (1977), in a survey of airtanker bases in the six western States in August 1974, indicated 59 percent of the 73 aircraft located at 47 different bases always sit loaded, while 43 percent sit loaded occasionally, and only 5 percent never sit loaded. Although the requirement to sit loaded in some instances is questionable, it occurs in practice for a number of reasons, frequently during periods of high fire danger. The present cost of retardant has already led to requirements such as "airtankers shall land with a retardant load equivalent to their maximum gross landing weight," which will undoubtedly promote the practice of aircraft sitting loaded. The question then is: How long must the mixed retardant be stable? In other words: How long will it hold color, not lose viscosity, or not spoil? Current specifications require 4-hour retardant stability if the mixed retardant is derived from a liquid, and 1 year if derived from a dry product. Separation will not alter the performance of the product in either case. The proposed single specification for retardant from liquid or dry components required a 30-day storage period. This

[8]USDA Forest Service. 1976. Airtanker performance guide for Rosenbaum tank in Evergreen B-17 aircraft (tanker 22). 13 p. USDA For. Serv., Intermt. For. and Range Exp. Stn., North. For. Fire Lab., Missoula, Mont.

rationale was used in determining the test matrix to be used in the evaluation and in interpreting the results.

From the results of the tests, no problem is perceived in the long-term storage of the components used in the Megatard 2700 system—that is, either the liquified ammonium sulfate or the dry thickener package. Once the components are mixed the product has fairly good stability; separation occurs but does not significantly affect performance for Megatard 2700A. Viscosity loss over a 30-day period was about 12 percent and at the end of 1 year about 80 percent. Megatard 2700B viscosity loss was higher—39 percent after 30 days storage. As with most gum-thickened products, initial viscosity and rate of development are dependent upon dispersal of the thickener and shear rate during mixing. A gradual loss in viscosity occurred with time; however, no indication of spoilage was observed. A definite performance advantage exists in using Megatard 2700A instead of 2700B in terms of mixed retardant stability (viscosity and separation). The presence of sodium ferrocyanide as a corrosion inhibitor appears to increase the deterioration rate of the gum-thickener although it does slightly reduce the corrosion rate of aluminum and brass when exposed to the solution. Quality of the mixed product can be enhanced by periodic recirculation, although this is not practical after the retardant is mixed and loaded in an aircraft.

One area where the performance of Megatard 2700 is less than desirable is in the area of corrosion. Although Megatard 2700A and Megatard 2700B met present uniform corrosion requirements for aluminum (less than 1 mil/yr using standard Magna Corrater total immersion procedures), the corrosion to mild steel exceeded present 1 mil/yr limits. The average uniform corrosion rate on mild steel exposed to Megatard 2700A was 5.22 mils/yr for the liquid component and 3.90 mils/yr for the mixed retardant, while Megatard 2700B gave a corrosion rate on mild steel of 10.2 mils/yr using the same test procedure and conditions. The corrosion rate for brass exceeded 1 mil/yr for Megatard 2700A, while Megatard 2700B had a corrosion rate well below 1 mil/yr (2.86 mils/yr for Megatard 2700A and 0.07 mil/yr for Megatard 2700B). Results obtained using the standard corrosion test and results of corrosion testing performed by Ocean City Research Corporation under Forest Service contract (Gehring 1974, 1978) led to several additional tests. These were thought to be more meaningful in quantifying corrosion expected during operational use and in testing of some formulation combinations and modifications in hopes of reducing corrosion without significantly affecting other performance characteristics.

Additional testing and formulation modifications demonstrated that if the inhibitors of Megatard 2700A and 2700B were incorporated into a combined formulation and 2 percent diammonium phosphate substituted for 2 percent ammonium sulfate, all present corrosion requirements could be met. Another alternative nearly as good is to use ammonium thiocyanate in combination with 1 to 2 percent diammonium phosphate. Increasing the concentration of diammonium phosphate from 1 to 2 percent reduces the uniform corrosion of mild steel and brass. (The corrosion rate on mild steel was below 1 mil/yr; however, the corrosion rate on brass was reduced to only 2 mils/yr.) Test data (table 8) show that the slight addition of sodium ferrocyanide in addition to ammonium thiocyanate and diammonium phosphate will eliminate the brass corrosion problem (reduce brass corrosion rate to about 1 mil/yr).

The fallacy in the 1 mil/yr mild steel requirements and test procedure is that operational experience and research studies conclusively show the primary corrosion problem with mild steel exposed to ammonium sulfate based fire retardant solutions occurs at and above the liquid/vapor interface and not primarily below the liquid surface. Fire-Trol 100, for example, is an inhibited ammonium sulfate based retardant that consistently exhibits total immersion rates of less than 1 mil/yr. Significant mild steel corrosion, however, occurs under field conditions; and laboratory studies show that partial immersion and vapor zone corrosion rates, determined by weight loss measurements after a 90-day exposure at 120° F, are as high as 5 to 15 mils/yr (the proposed requirement is less than 2 mils/yr at 70° F). Existing corrosion data indicate that corrosivity of the Megatard products to mild steel is generally similar to Fire-Trol 100.

Additional testing using total immersion and partial immersion weight loss procedures substantiated these data. Megatard 2700A gave low corrosion rates, less than 1 mil/yr, by weight loss procedure for aluminum, mild steel, and yellow brass under total immersion conditions at both 70° F and 120° F. Megatard 2700B only exceeded 1 mil/yr on mild steel at the 120° F condition (1.97 mils/yr was obtained). Corrosion rates with all products increased with temperature and under partial immersion conditions. Using partial immersion, Megatard 2700A had advantages with yellow brass while Megatard 2700B had an advantage with steel. These advantages are not consistent with the results of total immersion Corrater tests previously discussed.

Further testing could be done to verify that a combination of inhibitors can actually reduce weight loss corrosion under total and partial immersion conditions. However, a combination of the inhibitors of Megatard 2700A and 2700B (ammonium thiocyanate and sodium ferrocyanide) at 0.5 percent, and substitution of 2 percent diammonium phosphate for 2 percent ammonium sulfate, results in corrosion rates of less than 1 mil/yr with all three alloys required in present corrosion specifications and using present test procedures. All formulations and modifications of 2700A and 2700B included in the evaluation met aluminum uniform corrosion requirements, which are the primary concern in aircraft maintenance and safety. Intergranular corrosion of aluminum was not detected on either the exposed Corrater probes or test coupons used in weight loss tests (both total and partial immersion).

Results of corrosion tests at the Northern Forest Fire Laboratory using the Megatard 2700 formulations and by Gehring (1974, 1978) of Ocean City Research Corporation using inhibited ammonium sulfate solutions (without color or thickener), support one of the initial premises and a factor in the design of the test matrix, that is, neither the removal of iron oxide coloring, nor presence of the thickener would have a significant effect on the corrosive properties of the sulfate-based formulation.

The best overall choice (considering only the two original Megatard formulations) is probably 2700A, which provides the lower mild steel corrosion. Brass is primarily exposed to retardant in ground equipment and often can be avoided during hardware selection. Mild steel is more commonly found in ground storage and transfer equipment. A Megatard formulation composed of 0.5 percent ammonium thiocyanate, 0.5 percent sodium ferrocyanide, 2 percent diammonium phosphate (white-acid produced), and 13 percent ammonium sulfate appears to offer advantages over both Megatard 2700A and 2700B. For one, it would not be expected to alter performance to any extent from the Megatard formulations (as per other requirements and test procedures) with the exception of combustion regarding effectiveness, which would be expected to improve if the 2 percent diammonium phosphate were added.

To summarize, two advantages of the Megatard system that should be considered are: (1) gum-thickened products have improved stability and drop performance; and (2) formulations using ammonium sulfate should be considerably cheaper than those using either ammonium phosphate or ammonium polyphosphate. Two disadvantages of the Megatard system are: (1) For the same capability (gallons of mixed retardant) the Megatard system will require more storage capacity (for the 28 percent ammonium sulfate solution) than present formulations. The storage could be reduced considerably if the dry component (ammonium sulfate and corrosion inhibitor package) were stored at the base or in close proximity. (2) Significant corrosion to mild steel is to be expected (similar to that experienced with Fire-Trol 100). It appears, however, that formulation changes can effect a reduction in this characteristic.

We recommend that parameters not quantified in this evaluation per present and proposed specifications be investigated. These should include tests for which San Dimas Equipment Development Center has responsibility; that is, abrasion and erosion, pumpability, color, health, and safety. We recommend that a preliminary "value analysis" be conducted that would consider the trade-offs between performance and reduced cost as a result of the use of ammonium sulfate in relation to requirements stated in present unthickened liquid, thickened dry, or proposed combined specifications. The historic use of similar, currently approved products and their impact on maintenance and replacement costs should be included. Storage containers of stainless steel, fiberglass, polypropylene, or other inert materials should be considered as an alternative to mild steel. If results of the recommended tests and analysis are positive, an operational system should be evaluated (including full complement of storing, proportioning, transferring, and loading equipment). The evaluation should assess all system variables not measured in the laboratory. The operational evaluation should provide the information needed to complete a cost-benefit analysis.

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This report discusses a proposed new fire retardant system and the laboratory analysis and evaluation of the retardant solution produced. The demand mix system uses an ammonium sulfate based concentrate to which a gum-thickener (with or without coloring) is added as the solution is delivered to the aircraft. Attention is given to the physical and chemical characteristics and performance of the final retardant solution. Suggestions are presented for potential product improvement and recommendations are made for further evaluation and a cost-to-benefit analysis.

KEYWORDS: fire retardant, retardant evaluation, USDA specification, ammonium sulfate, corrosion, hydration, viscosity

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Intermountain Forest and Range Experiment Station

General Technical Report INT-113

April 1981

Determining Airtanker Delivery Performance Using a Simple Slide Chart-Retardant Coverage Computer

Charles W. George

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RESEARCH SUMMARY

Retardant coverage computers/slide charts have been developed for many aircraft and tank and gating systems in the national airtanker fleet. The computers indicate retardant delivery performance for specific tank and gating systems, and recommend coverage levels for various fuel/fire situations. The computers summarize data found in published airtanker performance guides and provide additional information regarding safe drop heights. The computers provide a simple, inexpensive method for identifying important performance characteristics of different airtankers and for selecting the most effective drop configurations. This report discusses development of the computer and provides instructions and examples of use.

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INTRODUCTION

To employ airtankers most efficiently, fire managers and air attack personnel must recognize the performance characteristics of many different types of airtankers and tank and gating systems. The airtanker pilot and lead plane pilot must select the volume of retardant to be dropped, the drop configuration, and the release interval for multi-compartment drops for the specific fuel and fire situation. To aid personnel, airtanker performance guides have been developed. Like an instruction manual for an instrument, the guides present performance data on specific aircraft and tank and gating systems, for alternative drop configurations, release sequences, and drop heights (George 1975a; Swanson and others 1976).

The national airtanker fleet currently numbers more than 100 airplanes incorporating about 50 different tank and gating systems, each having specific performance characteristics. Airtanker performance guides have been developed for many of the aircraft and delivery systems, and additional guidelines are planned for those not now covered. Although the performance guides are available and relatively easy to use, there is a need for a simple, inexpensive reference that can be used in real-time to identify and delineate primary performance. To satisfy these goals, airtanker performance "slide charts" (retardant coverage computers) have been developed (fig.1).

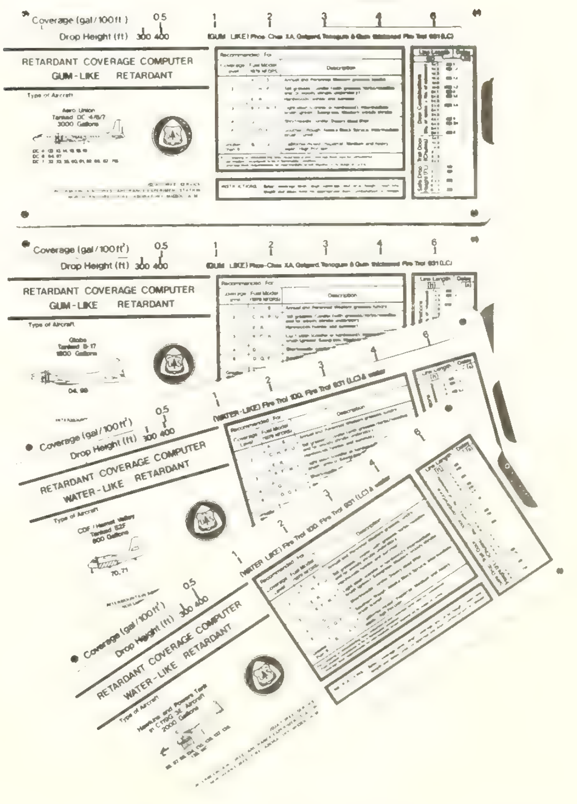

Figure 1.--Retardant coverage computers for specific airtankers have been developed to depict performance under a variety of conditions.

The retardant coverage computers allow quick determination of the best drop configuration for a given drop height and desired retardant coverage level for both waterlike and gum-thickened retardants. The computers provide the correct time interval between compartment releases for trail

or sequential drops and the maximum length of line that can be expected at selected retardant coverage levels. The coverage computers also provide an estimate of the safe drop height for various retardant volumes to avoid injury to men or damage to equipment on the ground. Individual computers are necessary for each type of delivery system because of the large amount of data involved: retardant type, drop heights, retardant coverage levels, drop combinations, individual trail drops, door delay intervals, and safe drop heights. The amount of data and the method of derivation render individual coverage computers more practical than other approaches, for example, the handheld programable calculator.

The purpose of this report is to describe the retardant coverage computer and the information it contains, and to illustrate its application.

RETARDANT COVERAGE COMPUTER INFORMATION

Aircraft and Tank and Gating System Description

The ability of air attack personnel to use airtankers most efficiently has been hampered by the large number of different aircraft and tank and gating systems. Due to the mobility of airtankers and practices of deployment, an air attack specialist may frequently encounter airtankers with which he is unfamiliar. Knowledge of specific tank and gating systems (i.e., number of compartments, availability of trail release systems, general performance) is necessary to employ them efficiently. Because of these factors and the magnitude of differences in performance (even between the same type of aircraft) separate performance guides and coverage computers have been developed for each type of tank and gating system. Thus, one model of airplane may require several different coverage computers.

Each coverage computer provides for the identification of the aircraft type, tank and gating system, and all the individual aircraft for which it may be applicable. Each coverage computer is developed for a particular tank volume released. The volume for which a computer was developed is given as part of the identification information. Figure 2 illustrates the identification information shown in a window in the coverage computer for an Aero Union tanked DC-4/6/7 carrying 3,000 gallons. All Aero Union tanks for the DC-4, DC-6, and DC-7 are identical in design and construction although not all DC-4, DC-6, and DC-7's can carry 3,000 gallons. (The maximum retardant an aircraft can carry is determined by the characteristics of the specific aircraft.) Delivery performance differs with retardant capacity. Thus, for this tank and gating system, performance guides were developed for capacities from 1,800 to 3,000 gallons, in 200-gallon increments. The appropriate guide or coverage computer is selected based on the retardant volume being carried (which may vary with the performance of the aircraft or by the density-altitude, airport restrictions at the operating base, or the contract requirements). The 1,800- and 2,000-gallon Aero Union tanked DC-4/6/7 coverage computer will usually be used for the DC-4. The remaining computers would be used for DC-6 and DC-7 aircraft, depending on each aircraft's performance and conditions of use.

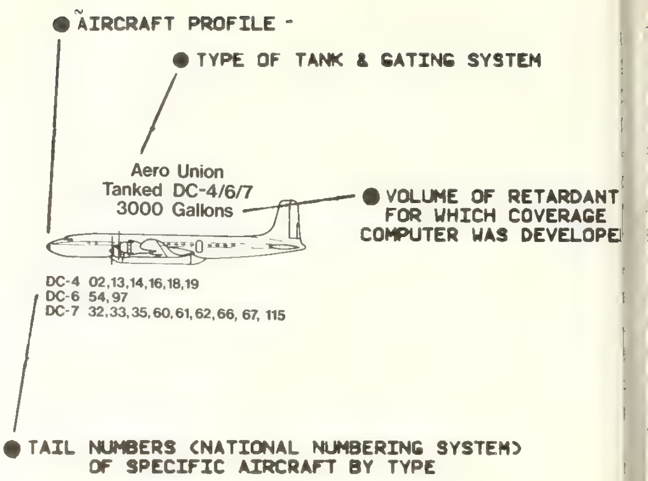

Figure 2.--Example of identification information shown in the I.D. window of a Retardant Coverage Computer.

The numbers below the aircraft profile in the identifica tion window refer to the tail numbers for specific aircra The numbers are assigned as airtankers are approved b the Interagency Airtanker Screening and Evaluation Boar Each aircraft (specific serial number and N numbe receives a number that is to remain with that aircraft a long as it is in service (remains available as an airtanke in the national fleet). In the illustration discussed abov and shown in figure 2, tankers 54 and 97 can be identifie as DC-6 aircraft equipped with an Aero Union tank. Th performance guide and coverage computer applicable then determined by the retardant volume being carried. the volume carried is considerably different from that fo the existing guide (200 gallons or more), the performanc data will not be applicable and must be adjusted. Thi can be done as a percentage of volume adjustment or b using the more detailed "Procedures to Adjust Airtanke Performance Guides for Downloaded Operations (Luedecke and Swanson 1979a, 1979b).

Type of Retardant

The performance of retardant depends upon the physic or rheological properties (George 1975b; Andersen an others 1974a, 1974b, 1976). Retardants that have a hig effective viscosity and elasticity over the range of shea rates encountered during fluid release, deformation, an breakup have been shown to yield a larger mean drople size within the retardant cloud. Larger droplet size result in greater retardant recovery due to reduced evaporatio and drift. The clouds of larger retardant droplets ar considerably more wind resistant and provide pattern of higher average concentration. In the development o the airtanker performance guides (Swanson and other 1975, 1977), retardants were grouped into classes base on their delivery performance: **gumlike** retardants usuall containing guar gum thickening agents that yield a hig effective viscosity and elasticity, and **waterlike** retardant that exhibit little or no elasticity and a low effective viscosit (although a high apparent viscosity may be present, as th case with clay-thickened Fire-Trol 100).

The performance of the two classes of retardant in the attern simulation model (PATSIM), used to generate the ata contained in the retardant coverage computer, is overned by a rule for the percentage of retardant re-overed (Swanson and others 1977). The difference in etardant recovery in turn results in differences in the own-range and cross-range retardant distributions oattern lengths and widths at various coverage levels). he use of a constant rule for percentage recovery for all ircraft results in a conservative estimate of differences etween the two types of retardant in the performance uides and retardant coverage computers. (Further iscussion of the nature of the rules and the pattern simula-on can be found in the previous reference documents on ne development of the performance guidelines.)

The performance for gumlike and waterlike retardants or a given tank and gating system is displayed physically n separate sides of the retardant coverage computer. The etardant type is shown in bold print through a window oelling out **"GUM-LIKE"** or **"WATER-LIKE"** retardant. he specific retardant formulations for each type retardant re also printed on the slide-chart insert in the **"DROP-IEIGHT"** window (to be discussed later). The formulations s categorized by drop performance are:

(WATER-LIKE)	Fire-Trol 100, Fire-Trol 931 (LC), and water
(GUM-LIKE)	Phos-Chek XA, Gelgard, Tenogum, and Gum-thickened Fire-Trol 931(LC)

comparison of the difference in performance between the vaterlike and gumlike retardants can be made for any elected drop height, retardant coverage level, and drop onfiguration by simply flipping over the retardant overage computer without changing the slide. For xample:

A Transwest tanked DC-7 carrying 3,000 gallons of retardant will provide the following line lengths at a retardant coverage level of 3 gallons/100 ft² (gpc) from a drop height of 300 feet:

Drop configuration compartments released)	**Length of line in feet at 3 GPC**		**Percent increase in length for gumlike over waterlike retardant**
	Gumlike	**Waterlike**	
1	80	35	129
2	155	130	19
3	190	160	19
6	290	235	22

Examination of the above example and similar erformance data for other drop configurations, drop eights, and retardant coverage levels will illustrate that ne difference in performance for the two types of retardant aries with the type of tank and gating system (flow rate), rop size, drop configuration, and drop height. The omparison will also indicate that the performance (line ength) can differ from several percent to several fold.

Drop Height

Airtanker performance guides provide delivery performance data over a range of drop heights usually from 100 to 500 feet. The drop height is the **tape line altitude above the ground level.** Fuels will modify the pattern as retardant droplets within the cloud impact the fuel, are retained, reflected, or continue to drip from the fuel. A base-line performance must be established, however, to permit comparisons of tank and gating systems, retardants, effects of various drop conditions, etc. The performance guides and coverage computers can be thought of as providing a pattern description at the moment the retardant cloud enters the canopy or fuel complex. The effect of the fuel complex on the pattern (the resulting pattern on the ground) may be large (for dense heavy fuels) or insignificant (for light grass or brush fields). Retention of retardant by the aerial fuel and its impact on the retardant levels needed to slow or stop a fire in a given fuel system were considered when deriving the recommended retardant coverage levels and will be discussed in a subsequent section of this paper.

The effect of the fuel complex on retardant interception and final distribution is a function of the angle of entry of the retardant and its characteristics (droplet sizes, velocities, rheological properties, etc). Aerial fuels can be penetrated by (1) dropping from relatively high altitudes, which allows complete retardant breakup and vertical fall through the vertical openings of most stands, or (2) driving the retardant through the canopy by low-level attack. The most uniform coverage and efficient retardant distribution is generally attained when near-vertical fall of the retardant occurs and minimum fuel impacts are encountered, as illustrated in figure 3. The fuel complex shields certain areas as the angle of entry is increased. Usually, low-level attack is necessary only when low retardant volumes are being utilized.

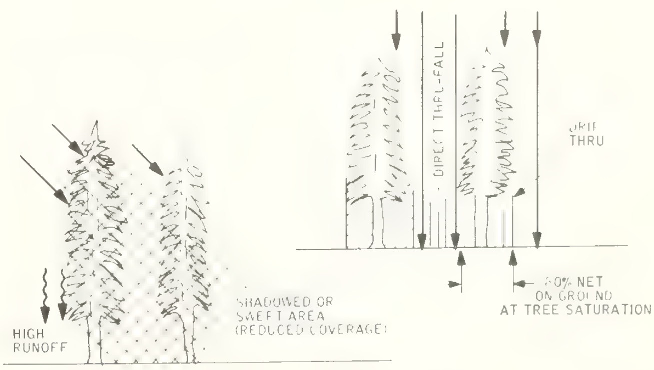

Figure 3.--Influence of drop height and retardant entry angle on overstory penetration.

The computers provide performance data for drop heights of 200, 300, and 400 feet **(above ground).** These heights were selected based on data regarding operational practices (a USDA Forest Service administrative directive enacted minimum drop height of 150 feet above the fuel

canopy for aircraft safety), safe drop heights (discussed in a later section of this paper), canopy height, and terrain considerations. To include additional heights would necessitate expanding the computer considerably. In addition, when considering performance and accuracy limitations, only slight differences occur for 100-foot versus 200-foot drop heights, but above 400 feet accuracy is drastically reduced.

To utilize the retardant coverage computer, the drop height is lined up with the retardant coverage (discussed later) and the maximum line length for each drop configuration read. The line length for any given drop height is a **maximum** predicted line length since these data were generated for low windspeeds (0-5 mi/h) and midrange drop speeds (usually 125 knots).

Recommended Retardant Coverage Levels for Fuel Models

Recommended retardant coverage levels were derived during the development of the airtanker performance guides (Swanson and others 1975). The coverage levels provide an important link between airtanker performance and the retardant required for a specific fuel/fire situation. In addition, in conjunction with pattern data they provide a basis for comparing the delivery performance of airtankers and for evaluating the effectiveness of airtanker operations (including tactics). The coverage levels recommended in the original airtanker performance guides were keyed to the nine fuel models of the National Fire-Danger Rating System (Deeming and others 1972). Coverage-level values were based on the maximum useful retardant concentrations calculated by Rothermel and Philpot (1975). The feature of a retardant-film thickness was also incorporated, using the original concept of Grah and Wilson (1944) and by determining the capacities of various vertical fuel models (Swanson and others 1973). These modifications to the model were used to refine estimates of the maximum useful retardant concentrations and hence as a basis to assign recommended retardant coverage levels.

The 1972 National Fire-Danger Rating System (NFDRS) was updated in 1977 (Deeming and others 1977) to correct deficiencies and to incorporate new technology. The number of fuel models in the 1972 NFDRS was expanded from 9 to 20 to more adequately represent the fuels encountered in the United States. In keeping with the refined fuel model descriptions, Rothermel[1] updated earlier estimates of fire retardant requirements. The estimates were based on the maximum useful retardant, the coverage of dry retardant required to minimize fire spread and intensity, (additional retardant will be of little value). Utilizing this information and the original recommended retardant coverage levels as displayed in the airtanker performance guides, an abbreviated table (fig. 4) was derived for use with the retardant coverage

Recommended For:

Coverage Level	Fuel Model[1] (1978 NFDRS)	Description
1	A, L, S	Annual and Perennial Western grasses; tundra
2	C, H, P, U E, R.	Tall grasses; Conifer (with grasses/forbs/needles and/or woody shrubs understory) Hardwoods (winter and summer)
3	K, F[2], N, T	Light slash (conifer or hardwood); Intermediate brush (green); Sawgrass; Western woody shrubs
4	G	Shortneedle conifer (heavy dead litter)
6	D, Q, F[2]	Southern Rough; Alaska Black Spruce, Intermediate brush (cured)
Greater than 6	B, I, J, O	California mixed chaparral; Medium and heavy slash; High Pocosin

For creeping or smouldering fires, reduction of one coverage level may be considered.
[1] Fuel models considered to be in flammable condition.
[2] Coverage level requirements for intermediate brush depend on its stage of curing.

Figure 4.--Recommended retardant coverage levels in gallons/100 ft^2 for the 20 fuel models described in the 1978 National Fire-Danger Rating System.

[1]Rothermel, R.C. 1978. Estimation of fire retardant requirements. Unpubl. rep. USDA For. Serv., Intermt. For. and Range Exp. Stn., North. For. Fire Lab., Missoula, Mont.

computers. Footnote 1 (to the recommended coverage levels shown in fig. 4) is based on the assumption that fuels are dry enough for the fire to spread. Under marginal burning conditions the retardant requirements shown in figure 4 are probably excessive. This is illustrated by the difference in retardant requirements for fuel model F where fuel condition (degree of curing) makes a significant difference in the retardant requirement (footnote 2 of fig. 4).

After determining the fuel model most appropriate for a given situation, the recommended retardant coverage level (in gallons/100 ft^2 or gpc) can be determined using the data in figure 4. The coverage level can then be used as a base-line value by which different tank and gating systems, release options, retardants, etc., can be compared. The behavior of the fire in any particular fuel situation must be used to temper or adjust selected coverage levels.

Drop Configuration

In the airtanker performance guides, performance of an airtanker/tanking system in constructing retardant line was given in detailed "maximum line length/tank-opening delay tables." Line length data were generated using the Pattern Simulation Model (PATSIM) and flow rate data on the specific tank and gating system for various methods of release. The simulation model increments retardant flow rate and flies each increment to extinction, distributes the retardant in space, and transforms it into a ground distribution pattern. A series of computer runs including different drop combinations, drop heights, etc., was then made. The output data (simulated ground pattern distributions) were then digested, line lengths at various coverage levels determined, release intervals to maximize line lengths determined, and the detailed line length tables developed. These tables were in turn summarized in "Best Strategy Charts" to allow quick identification of the drop configuration and release interval (delay) that gave the most efficient combination for any situation of coverage level, line length, and drop height.

The retardant coverage computer was designed to yield information similar to that of the Best Strategy Charts, with the exception that the maximum line length/release interval is given for each possible drop configuration, for coverage levels 0.5 to 6 gallons/100 ft^2 and drop heights of 200, 300, and 400 feet.

The retardant coverage computer was also designed to identify the type of releases possible for any given tank and gating system, yet was standardized in format so that one retardant coverage "sleeve or jacket" could be used for most aircraft/tank and gating systems. The format and layout shown in figure 5 lists all drop combinations (both trail and salvo) and covers most aircraft systems in use. The nomenclature for the door and trail combinations consists of the multiplication of two numbers; the first being the number of tanks or compartments released, the second being the number of releases making up the particular drop. For example:

> *For a 4x2 door combination, where: 4 denotes four compartments or tanks are released at once, and 2 denotes two releases of four compartments were made.*

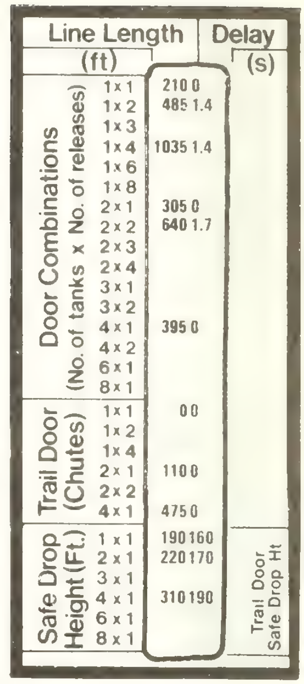

Figure 5.--Retardant coverage computer layout providing door combination/line length and delay and safe drop height information. (This example is for a Hemet Valley/Aero Union tanked C119G-3E with gum-thickened retardant, coverage level 2, and a 200-foot drop height.)

The maximum line length (in feet) and delay interval necessary to attain that line length are shown adjacent to the door or trail combination through a slot in the retardant coverage computer sleeve. Hence, the number of combinations (door and trail) are easily determined by observing those combinations having line length/delay data. For example, in figure 5, the retardant coverage computer data (for the Hemet Valley/Aero Union tanked C119G-3E) indicates a four-compartment tank system with trail capability. (Line length data exist for 1x1, 1x2, 1x4, 2x1, 2x2, and 4x1 door combinations in addition to 1x1, 2x1, 2x2, and 4x1 trail door combinations.) The line length attainable for each of the drop/door combinations is adjacent to each combination. For other than salvo releases (all tanks at once), the delay or release interval is given in seconds. For the 1x4 door combination release shown in figure 5, 1,035 feet of line can be attained when the four compartments are released with a 1.4-second delay between each single compartment release.

The retardant coverage computer permits the quick determination of the best drop configuration and release to maximize the line length for a specific drop height, retardant type, and desired coverage level. Different drop configurations can readily be compared as can the interrelated effects of drop height and retardant type.

Safe Drop Height

Retardant drops have the potential for injuring personnel on the ground. Large unbroken quantities of retardant may hit firefighters or may dislodge tops of trees, brush, logs, loose stumps, rock, etc., which can injure firefighters. Airtanker pilots and air attack specialists, working in populated areas or in the support of ground personnel, are constantly concerned about firefighter safety.

Recent accidents and incidents have caused managers to consider present operational practices in terms of both safety of the aircraft and firefighters on the ground. In the interest of aircrews a minimum drop height of 150 feet

above the canopy or highest obstacles has been administratively imposed (discussed previously). Large-capacity airtankers, generally having higher retardant flow rates, have also contributed to the mounting number of on-the-ground incidents and accidents. This growing concern led to an attempt to quantify "safe drop heights" so that they might be displayed in the retardant coverage computers.

Flow rate data, pattern data, and photographic data concerning retardant breakup for various airtankers were studied. The rate of deformation, breakup, and retardant cloud formation is a function of the drop volume and the flow or evacuation rate. Retardant breaks up more slowly from tank and gating systems having larger flow rates at comparable volume (produces greater vertical penetration) than from tanks with slow flow rates (such tanks have a greater capability to provide higher retardant coverage levels). An equation was derived that correlated the vertical penetration (safe drop height) with volume and flow rate. Although the data varied due to effects of tank and release geometry, etc., the relationship was satisfactorily used to define a lower limit of penetration for different tank and gating systems.

The vertical penetration was defined as the vertical distance below the aircraft where total breakup occurred. This is also the point at which forward trajectory and velocity stop. Figure 6 illustrates the point at which penetration is calculated. At drop heights less than the penetration value, the impact of the uneroded retardant can be expected to be hazardous, depending upon the situation.

Using the flow rate for each drop configuration and the derived relationship, a safe drop height can be estimated. The retardant coverage computer displays the safe drop height value for each drop or door configuration (fig. 5). Because the values do not change with coverage level for each salvo configuration, they are identical for all settings of the slide chart. Safe drop heights are identical for both gumlike and waterlike retardant. Although differences exist, they are so minor in comparison to effects of tank geometry that they are omitted. (Retardant type becomes an influence after the retardant is stripped from the central mass and during further breakup, cloud formation, and settling.)

For the example shown in figure 5 for the Hemet Valley/Aero Union tanked C119G-3E, the safe drop height in feet was displayed:

Door combination	Safe drop height (ft)
1x1	190
2x1	220
4x1	310

This means that a single drop (500 gallons) from less than 190 feet over the fuel complex may not break up and may endanger firefighters. Similarly, a salvo drop (4x1 of 2,000 gallons) does not completely break up until a penetration height of 310 feet is reached. Safe drop heights are quite high for this particular airtanker because it has one of the highest flow rates. Thus, the retardant coverage computer provides a quick reference and estimate of the safe drop height above the fuel under low wind conditions (0-5 mi/h). The minimum safe drop height, of course, decreases with increased wind as does the optimum drop height for retardant effectiveness.

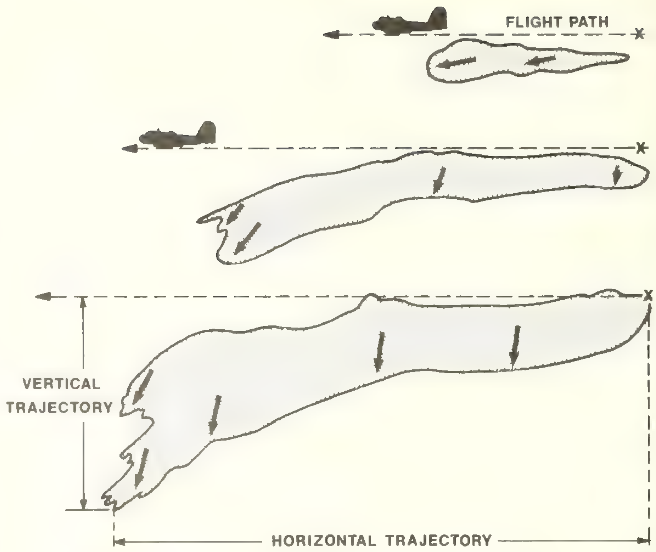

Figure 6.--Diagram showing the method for identifying and determining the penetration or vertical trajectory of retardant drop.

INSTRUCTIONS FOR USE

Once the information provided by the retardant coverage computer/slide chart is fully understood, the mechanics of using it are very simple. A brief outline of the steps follows:

1. Select the appropriate computer for the aircraft to be used. This can be accomplished by identification of the type of tank and gating system, or by reference to the national airtanker number system. (The latter step should be taken to verify the appropriate slide chart has been selected.) If a coverage computer is not available for that specific airtanker, it may be possible to select one having similar performance if one possesses a thorough knowledge of the tank and gating system. (Table 1 lists airtankers by type of tank and gating system for which retardant coverage computers are available.)

2. Select the proper side of the retardant coverage computer for the type of retardant to be employed in the operations. This will be **GUM-LIKE** retardant (such as Phos-Chek XA, Gelgard, Tenogum, or gum-thickened Fire-Trol 931 [LC]) or **WATER-LIKE** retardant (such as Fire-Trol 100, unthickened Fire-Trol 931 [LC] or water.)

3. Select from the Recommended Retardant Coverage Level chart (one located on each side of the coverage computer) the appropriate coverage level for the fuel and fire situation. Modify the coverage level for unusual fire characteristics or behavior (for example, reduce the coverage level if the fire is creeping or smoldering) or based on experience if necessary.

4. Estimate the drop height limits:

   a. To assure aircraft safety in clearance of terrain features during the maneuver (150-foot minimum above canopy is an often imposed administrative limitation), and

   b. To protect ground personnel in close-support operations (the safe drop height will be verified after the best drop configuration is identified and may necessitate a change in drop height.)

Table 1.--Aircraft/tank and gating systems for which retardant coverage computers/slide charts are available

Type aircraft/ tank and gating system	Applicable volume	Numbers of aircraft having tank and gating system
	Gallons	
CDF/Hemet Valley tanked S2F	800	70, 71
CDF/Aero Union tanked S2F	800	72, 73, 74, 75, 76, 77, 78, 79, 80, 90, 91, 92, 93, 94, 95, 96, 100
Ralco tanked PV-2	1,000	38, 39
Reeder tank/Lynch Stol B-26	1,200	58
Canadair CL-215	1,400	All Canadair CL-215
Evergreen/Rosenbalm B-17'	1,800	22
Globe tanked B-17	1,800	04, 99
Black Hills tanked B-17	1,800	09, 12
Aero Union tanked DC-4/6/7	1,800-3,000	DC-4 02, 13, 14, 16, 18, 19 DC-6 54, 97 DC-7 32, 33, 35, 60, 61, 62, 66, 67, 115
W.A.I.G. tanked DC-4	2,000	113, 118, 119, 160
Hemet Valley/Aero Union tanked C119G-3E	2,000	81, 82, 86
Hawkins & Powers tanked C119G-3E	2,000	36, 87, 88, 134, 135, 136, 137, 138, 139, 140
Hawkins & Powers tanked PB4Y2	2,200	30, 121, 122, 123, 124, 126, 127
Black Hills tanked P2V-5	2,450	05
Black Hills/Rosenbalm tanked P2V-7	2,450	08, 11
Central Air Services DC-7	3,000	110
Transwest tanked DC-7	3,000	28
SIS Q/Rosenbalm tanked DC-6/7	3,000	20, 21, 44, 45, 46, 47, 48, 51
C-130 MAFFS	3,000	All C-130 Maffs

5. Align the desired retardant coverage level with the estimated drop height on the coverage computer and read the maximum length of line that can be expected for each alternate drop configuration (including trail drops). For other than salvo drops the required delay interval in seconds is adjacent to the line length.

6. Assess the line length that can be made with that needed for the particular operation, tactic, or strategy and select the best drop configuration.

7. Reevaluate the drop height limits in terms of the safe drop height for the selected drop configuration and adjust if necessary.

8. If unusual drop conditions exist, such as higher than normal wind conditions, consider selecting a higher retardant coverage level, lower drop height, or both (lower drop height for accuracy and performance, higher coverage level for increased retardant dispersion and aircraft safety margins).

9. Repeat steps 3-8 as adjustments are necessary (for example, as performance is observed in real-time fire operations).

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Slide chart computers have been developed to guide application of fire retardant from airtankers. The computers predict delivery performance for tank and gating systems on specific aircraft and recommend coverage levels for various fuel and fire situations. The devices also enable personnel to calculate safe drop heights, length of retardant line, and most effective drop configuration. The computers cover both gumlike and waterlike retardants and are available for many aircraft and tank and gating systems in operation.

KEYWORDS: fire retardant, aerial delivery, tank and gating system, performance guides, retardant coverage levels, fuel models, drop height, release sequence, safety

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

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United States
Department of
Agriculture

Forest Service

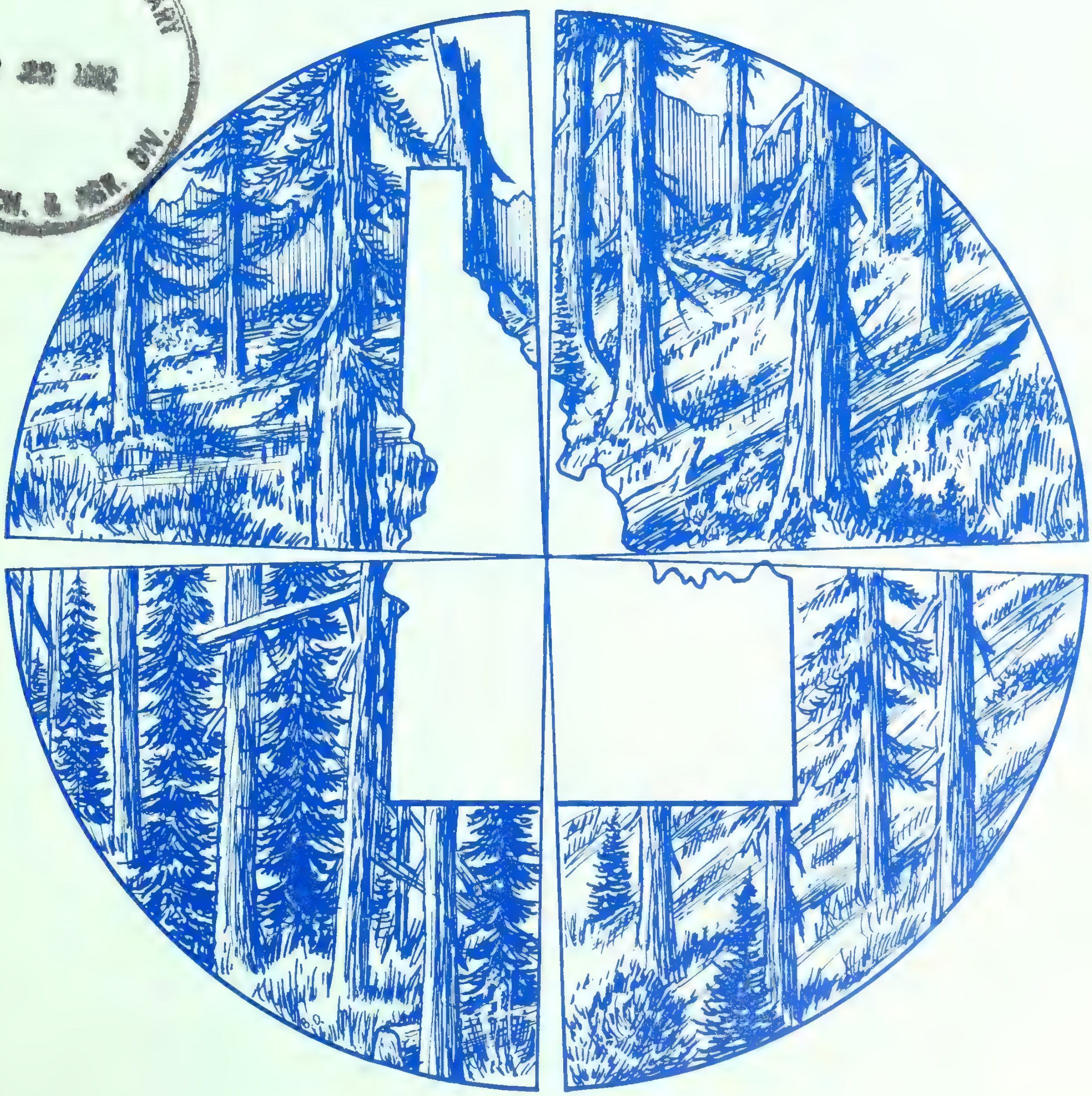
**Intermountain
Forest and Range
Experiment Station**

General Technical
Report INT-114

September 1981

Forest Habitat Types of Central Idaho

**Robert Steele
Robert D. Pfister
Russell A. Ryker
Jay A. Kittams**



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OBERT D. PFISTER, principal plant ecologist and leader of the Forest Ecosystems research work unit initiated and directed this comprehensive effort following initial sampling in the subalpine forests. He had a continuing role in shaping and reviewing various stages of the classification. He joined the Intermountain Station staff in 1961 as a research forester in western white pine silviculture in northern Idaho. He holds B.S. and M.S. degrees in forest management from Iowa State University and Oregon State University, respectively, and a Ph.D. in botany from Washington State University.

USSELL A. RYKER, project leader of the Ecology and Silviculture of Rocky Mountain Douglas-fir and Ponderosa Pine Ecosystems research work unit at Boise, Idaho, initiated sampling in *Pseudotsuga* forests prior to the combined study. He has continued to review various stages of the classification and was instrumental in shaping the management implications for many of the habitat types. He received B.S. and M.S. degrees in forestry from the University of Missouri and conducted research in the silviculture of hardwoods for the North Central Experiment Station prior to joining the Intermountain Station in 1963.

AY A. KITTAMS, now forester on the Tongass National Forest, was a forestry technician for the Intermountain Station in Boise, Idaho, and shared responsibility for much of the field sampling and data processing. He earned a B.S. degree in forestry from the University of Montana and began his Forest Service career in 1968 at the Northern Regional Aerial Fire Depot. He joined the Intermountain Station at Boise in 1971.

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The interpretations of forest habitat types for wildlife values were developed through contributions from Cecil Brown, Bill Hickey, and Walt Bodie (Idaho State Fish and Game Department), Hadley Roberts (Salmon National Forest), Dean Doell (Boise National Forest), Tom Phillips (Sawtooth National Forest), Dr. Dean Medin (Intermountain Station), and Dr. Edward Schlatterer (Intermountain Region). Richard Johnstone (Bureau of Land Management) donated his data from a 5-month study of nongame wildlife in east-central Idaho. The contributions of these people made it possible to expand the written information on wildlife values in the habitat type descriptions.

Norm Bare (Sawtooth National Forest), Laverne Nelson (Salmon National Forest), Richard Thompson (Payette National Forest), and George Wendt (Boise National Forest) identified parent materials and soil textural classes. James Clayton (Intermountain Station) also assisted with identification of parent materials. John Arnold (Boise Zone Office) supplied information on land systems and their relationship to vegetation. Dr. Walter Megahan (Intermountain Station) provided additional weather data from forest habitats.

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David Ondov (Intermountain Station) conducted the computer programing and much of the data processing. Summer assistants Gaylen Jones and Virginia Graham handled numerous laboratory duties and endured many long hours in the field. Dr. Stephen Arno and Bernard Kovalchik (Intermountain Station) provided several helpful reviews in relation to similar work they had completed in Montana. Others who reviewed the manuscript and offered helpful criticism were Frederic D. Johnson (University of Idaho), Dr. Stephen Cooper (University of Nevada), Ron Hamilton (Salmon National Forest), Earle Layser (Bridger-Teton National Forest), Dr. Edward Schlatterer, Al Dahlgreen, and Kermit Larson (Intermountain Region), and Dick Stemple (Boise National Forest).

RESEARCH SUMMARY

A land-classification system based upon potential natural vegetation is presented for the forests of central Idaho. It is based on reconnaissance sampling of about 800 stands. A hierarchical taxonomic classification of forest sites was developed using the habitat type concept. A total of eight climax series, 64 habitat types, and 55 additional phases of habitat types are defined. A diagnostic key is provided for field identification of the types based on indicator species used in development of the classification.

In addition to site classification, descriptions of mature forest communities are provided with tables to portray the ecological distribution of all species. Potential productivity for timber, climatic characteristics, surface soil characteristics, and distribution maps are also provided for the types. Preliminary implications for natural resource management are provided, based on field observations and current information.

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Forest Habitat Types of Central Idaho

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INTRODUCTION

The forest vegetation of central Idaho presents a complex array of composition and structure. As a result, people who manage these lands need classifications that reduce this diversity to a reasonable number of units. Technical classifications such as forest cover types have limited applicability beyond the specific use for which they were developed. In contrast, natural classifications not structured for a specific use can have wide application and need not be changed as management objectives change. In the long run, natural classifications can accommodate the greatest number of applications because they reflect existing patterns in nature and avoid arbitrary delineations.

Natural classification of forest ecosystems by habitat type has proven useful in forest management and research; application has expanded rapidly over the last decade (Layser 1974). Similar classification systems have now been developed for about 20 areas in the western United States (Pfister 1976). This widespread use reflects recognition of the need to emphasize management of ecosystems rather than individual resources. Specialists in different resources also recognize the need for a common medium for communication, management decision, and research application.

The habitat type system of site classification was initially developed over a 20-year period by Daubenmire (1952) for forests of northern Idaho and eastern Washington. Later, R. and J. Daubenmire (1968) refined their original system. Since then it has served as a model for classification of other areas. After considering other approaches, the Intermountain Forest and Range Experiment Station and the Intermountain Region of the USDA Forest Service began a cooperative study in 1972 to classify forest habitat types of central Idaho. This study has been closely coordinated with a similar study initiated in Montana in 1971 (Pfister and others 1977).

Study Objectives and Scope

The objectives of this study were:

1. To develop a habitat type classification (taxonomy) for the forested lands of central Idaho based on potential climax vegetation.

2. To describe the general geographic, topographic, climatic, and edaphic features of each habitat type. (A glossary is provided in appendix G.)

3. To describe the late seral and climax communities characteristic of each type.

4. To provide information on successional development, timber productivity potential, and other biological observations of importance to forest land managers.

5. To develop and test a reconnaissance-plot method of data gathering that allows development of a habitat type classification in a minimum period of time.

The area covered by this classification extends from the northern edge of the Snake River Plains north to the Salmon-Clearwater divide and from Hells Canyon east to the Montana border (fig. 1). This area of about 16.6 million acres (6.7 million hectares) includes five National Forests and adjacent forest land regardless of ownership. Flood plains dominated by broadleaved trees and minor areas of *Juniperus osteosperma* in the southeast were not included. Likewise, pure stands of *Populus tremuloides* are not part of this classification but are noted at the series level.

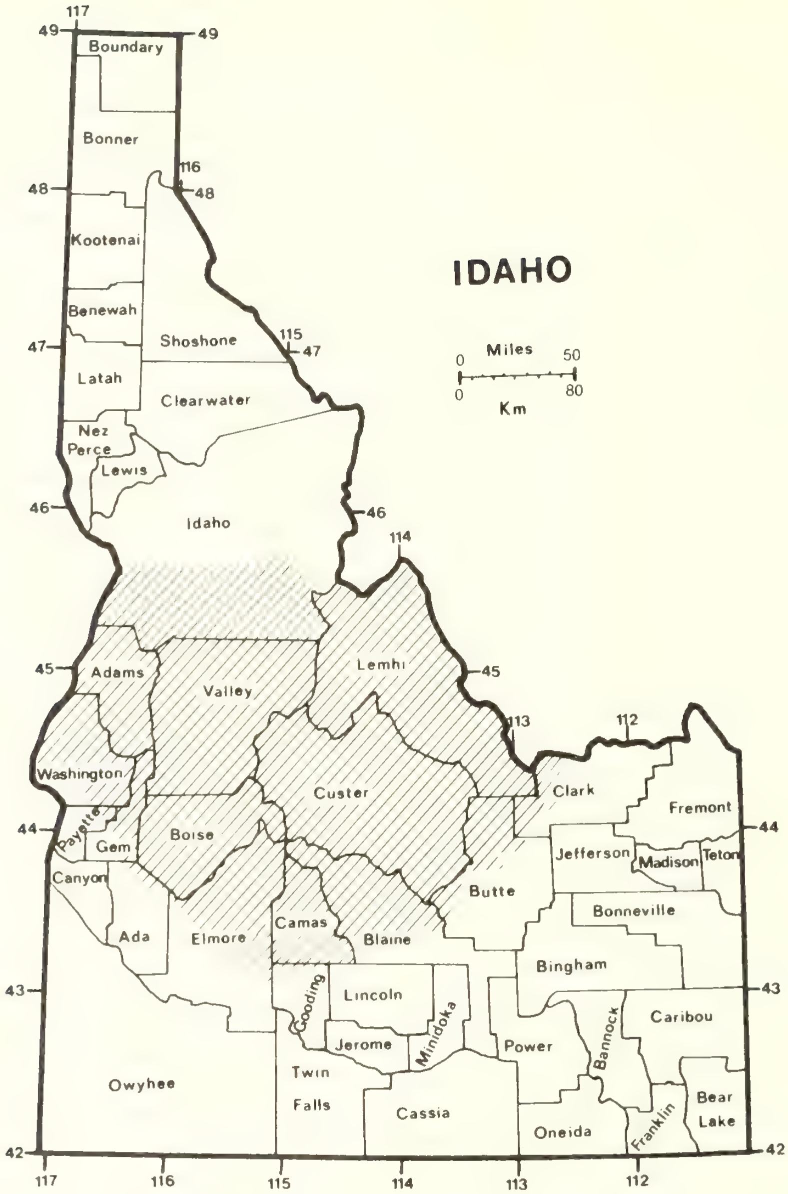


Figure 1. — The portion of Idaho (hatched area) covered in this study.

METHODS

Field Methods

The fundamental technique for collecting field data was to efficiently sample a full range of environmental conditions in central Idaho forests. Random and systematic sampling procedures were considered inefficient and impractical for this study. Instead we adopted a sampling technique similar to the "subjective, without preconceived bias" method supported by Mueller-Dombois and Ellenberg (1974). This basic philosophy was applied to all three steps of plot location: (1) selecting road transects, (2) selecting stands, and (3) placing the plot within the stand. With this approach, plots were not selected by the probable placement of a stand within any classification or by applicability to specific management problems.

Elevational road transects were selected to reflect the full range of environmental conditions in central Idaho forests. Usually the team leader made note of potential sites as he reconnoitered the transect. Brief stops were made to inspect undergrowth composition; overstory and general undergrowth patterns were observed en route. On the return trip, mature stands that best represented the different kinds of plant communities for that area were selected for sampling.

Plots were located within a homogeneous portion of the stand to provide a representative sample. To do this, the team leader examined the tree canopy from the road. For uneven-aged stands, the largest tree or group of trees in the stand was chosen as the plot center. For even-aged stands, the center of the largest homogeneous expanse of tree canopy was used. Upon reaching the predetermined spot in the stand, the sur-

rounding area was examined to insure that the sample plot would represent the stand. If the sample plot included ecotones, obvious microsites, or severe disturbance, it was relocated to avoid these conditions.

Plot center for a 375-m² (about one-tenth acre) circular plot was marked with a labeled wooden stake. The plot center was referenced to a roadside feature to enable revisitation during the study.

Trees more than 4.5 ft tall were tallied by 2-inch d.b.h. classes according to species. Trees between 0.5 and 4.5 feet in height were recorded by species in a 50-m² circular plot.

Amounts of all vascular plant species were estimated by seven canopy-coverage classes (+ = present in stand but not in plot, T = 0-1 percent coverage, 1 = 1-5 percent, 2 = 5-25 percent, 3 = 25-50 percent, 4 = 50-75 percent, 5 = 75-95 percent, 6 = 95-100 percent). For maximum efficiency, these coverages were estimated within the entire 375-m² plot instead of the usual series of small quadrats (Daubenmire 1959). With practice and coordination among the samplers (including practice layouts within the plot representing areas of 1 percent, 5 percent, and 25 percent), it is possible to visualize and estimate coverage of all the plants by this one method. Accuracy may be less than where coverages are estimated in small quadrats, but the number of stands sampled in a day can be at least doubled, thus providing better sample coverage of the region. Coverage-class values can be used directly in association tables or in ordinations.

All unidentified plants on each plot were collected and preserved for later identification or verification. Many plants in flower were also collected for voucher specimens.

A relatively free-growing tree of each species present was measured for height, age, and diameter in order to estimate site potential by species. Suitable site trees for each species were not always available, especially in the denser stands.

Plot aspect was obtained to the nearest 5 degrees with a compass. Slope (percentage) and tree heights were measured with a clinometer, and altitudes were estimated with a pocket altimeter.

Thicknesses of litter, fermentation, and humus layers were measured at three locations in the plot. Samples of the upper 20 cm (ca. 8 inches) of mineral soil were collected for laboratory analysis of percentage of coarse fraction and pH. Samples of the parent material were also collected when available.

Observations were made on fire history, insect and disease occurrence, animal use, and environmental position of the stand in relation to adjoining stands. This latter observation proved valuable during analysis of relationships between plant community types and environmental gradients.

Pfister and Ryker initiated this study on a part-time basis during 1970 and 1971 by sampling 82 stands on the Boise and Payette National Forests. During the summer of 1972, Steele and Kittams sampled 312 stands on a wide variety of environments in the same two National Forests. These data were combined and provided the basis for a preliminary habitat type classification for that area (Pfister and others 1973, unpubl. ref.)

The following summer (1973), Steele and Kittams sampled 277 stands throughout the Challis, Salmon, and Sawtooth National Forests. These data were combined with previous sampling by Ryker and with data from a study by Schlatterer (1972, unpubl. ref.). From these data, a preliminary classification for the Challis, Salmon, and Sawtooth National Forests (Steele and others 1974, unpubl. ref.) was derived.

Areas where previous data appeared inadequate were sampled in the summer of 1974. Considerable time was also spent examining areas peripheral to central Idaho to obtain additional data on types weakly represented in the study area and to insure future compatability with classifications on forest lands adjacent to central Idaho.

In 1975, the Nezperce National Forest was sampled and a preliminary classification (Steele and others 1976, unpubl. ref.) was made to link the central Idaho classification with that of R. and J. Daubenmire (1968) in northern Idaho. Eastern Idaho and western Wyoming were sampled in 1976, as were additional areas in the Lemhi, Lost River, and Beaverhead Ranges. A preliminary classification (Steele and others 1977, unpubl. ref.) for eastern Idaho and western Wyoming helped categorize some types in east central Idaho. Additional sampling in 1977 was directed mainly toward problem areas in central Idaho. Although all of the above data were considered when finalizing the central Idaho classification, only those data from central Idaho were used in the charts and tables presented herein.

Office Methods

Development of the classification followed the general procedures outlined below.

1. After each field season we listed prospective habitat types based on our field observations. New situations not conforming to classifications of adjoining areas were briefly described.

2. Voucher specimens of plants were identified and some were sent to other herbariums for verification. Unknown vegetative material was compared with identified flowering specimens. All positive identitications were entered on the field forms. Each species with occurrence in five or more stands was numerically

coded. All plot data were then keypunched for computer processing.

3. Synthesis tables (Mueller-Dombois and Ellenberg 1974) were computer-printed from the data available for our area. Synthesis tables were compiled for each preliminary classification (1973 and 1974) and the review draft (1975) and were updated and revised for the final publication. Stands were arranged according to general similarities of vegetal composition and relationships to existing classifications from adjacent areas. Separate tables were prepared for each series (all stands having the same climax tree species). The synthesis tables were studied in detail and those species that showed consistent differential distributions were underlined. Synthesis tables were rearranged several times to group those stands most similar in overall composition and to segregate groups with consistent differences. The final arrangement provided the formal basis for series, habitat types, and phases.

4. Following the summers of 1972 and 1975, several ordinations (Bray and Curtis 1957) were used to arrange the stands graphically on a quantitative basis of species composition and coverage. Because of the large number of stands involved, plots were grouped by climax tree species (series) prior to ordination. These analyses were used to review the previous stand groupings and the value of certain species as indicators. Occasionally new relationships were suggested. [Analysis of synthesis tables received greater relative emphasis in this study than in a similar concurrent study in Montana (Pfister and others 1977).]

5. Characteristic vegetational parameters for the habitat types and phases were identified, described, and then translated into a key to the habitat types. The key was then applied to all plot data on hand. Type descriptions and/or the key were revised to accommodate individual stand data.

6. Following the previous adjustments, constancy and average cover values were calculated for the important indicator plants. A presence list was prepared for all species represented in at least five stands to allow further evaluation of the distribution of species of interest.

7. Terminology for the types was adjusted to allow direct comparison with R. and J. Daubenmire (1968), Pfister (1972), Cooper (1975), and Pfister and others (1977), and to express the interrelationships of types as clearly as possible. The phase was used to subdivide habitat types based on consistent vegetative differences attributable to apparently minor environmental differences. In some cases, a phase represents a portion of a habitat type with some characteristic of an adjacent habitat type — for example, *Abies lasiocarpa/Vaccinium scoparium* habitat type, *Calamagrostis rubescens* phase. Phases may also distinguish geographic subdivisions of types having very wide distributions — for example *Pseudotsuga menziesii/Calamagrostis rubescens* habitat type, *Pinus ponderosa* phase.

8. Preliminary classifications (Pfister and others 1973, unpubl. ref.; Steele and others 1974, unpubl. ref.) were developed after each of the first two field seasons. The preliminary classifications, including brief descriptions of each type, were presented at training sessions in 1973 and 1974 and immediately put into use on central Idaho National Forests. User evaluations were solicited; among problems revealed were areas that needed more sampling.

9. The two preliminary classifications and 1974 data were combined in a review draft (Steele and others 1975, unpubl. ref.). Technical review and comments from field users in 1975 suggested additional sampling for problem areas. Supplementary data were collected in 1976 and 1977. These were included when developing synthesis tables, redefining types where necessary, rewriting the keys, checking all stands against the classification, and mutually agreeing on the types and phases. About 3 percent of our sample stands did not fit the resulting classification. Many of these evidently represented ecotones, vegetational mosaics, unusual seral communities, very dense stands with little undergrowth, or unique situations. However, it is also possible that some may either represent local habitat types for which we have insufficient data or habitat types that occur mainly in areas not yet studied.

10. A dot map showing the known locations of each habitat type was prepared using data from this study and supplemental data from several cooperators who were using the working classification for other field studies (see acknowledgments). As these distribution maps became more complete, the affinities of a habitat type to certain climatic or geologic influences became more evident and improved our understanding of each classified unit.

11. Each defined habitat type was described including a general discussion of physical environmental features, geographical distribution, key vegetational features, descriptions of phases and basis for their separation, and general implications for management.

12. An understanding of the environmental and vegetative features of each habitat type provided general guidance for many immediate management questions. Some of the more obvious relationships have been pointed out in the habitat type descriptions and discussion section. This classification serves as a foundation for development of further "site-specific" management implications by users of the system and in future research studies.

Taxonomic Considerations

Most plants were identifiable to species, but a few nonflowering specimens remained unidentified. Voucher collections, representing a few thousand plants, were compiled in the course of stand sampling.

About 2,000 of the better collections were deposited in the herbarium of the Intermountain Forest and Range Experiment Station at Boise. Many of the specimens were identified or verified by Mont E. Lewis (USDA Forest Service, retired) who in turn forwarded some specimens, especially the *Poa* and *Castilleja* spp., to Arthur H. Holmgren and Noel H. Holmgren, respectively, at Utah State University. Also, certain specimens were identified or verified by Dr. Douglass Henderson at the University of Idaho.

Taxonomic nomenclature originally followed Hitchcock and others (1955-69). A condensed edition (Hitchcock and Cronquist 1973) with minor revisions became available during the study and was consulted for the final nomenclature. For example, *Luzula glabrata* was changed to *L. hitchcockii* and *Antennaria rosea* to *A. microphylla.*

Stickney (1972, unpubl. ref.) found that essentially all of the *Vaccinium globulare-V. membranaceum* material collected in Montana would best be labeled *V. globulare.* Based on shape of flowers and leaves, most flowering material observed in central Idaho also best conforms to *V. globulare.* In our study area the strongest divergence from this generality appeared in a few areas from McCall northward where some specimens displayed intermediate characteristics. Thus we have chosen *V. globulare* as the epithet for this complex in central Idaho. Populations farther north, however, require additional investigation.

Special attention is needed to distinguish *Pinus albicaulis* from *P. flexilis. Pinus albicaulis* occurs mostly within the higher elevations of forest growth across central Idaho. *Pinus flexilis* occurs mostly in the eastern one-third of this area near lower timberline and extends to mid-elevations of the forested zone on dry exposed sites. Cones of *P. albicaulis* are somewhat purple and disintegrate on the tree, leaving only detached scales on the ground. Cones of *P. flexilis* turn from green to brown and fall to the ground intact.

In some areas, *Spiraea pyramidata* dominates undergrowth where one would expect to find *S. betulifolia* dominant. *Spiraea pyramidata* is considered by Davis (1952) and Peck (1961) but not Hitchcock and others (1955-69) to represent a hybrid between the dry site *S. betulifolia* and the wet site *S. douglasii.* Our reconnaissance has shown that *S. pyramidata* occupies an intermediate moisture regime between its two supposed progenitors. However, it appears to coexist more readily with *S. betulifolia* than with *S. douglasii.* For this reason *S. pyramidata* is used as an alternate indicator of *S. betulifolia.*

In the western half of central Idaho, *Symphoricarpos oreophilus* and *S. albus* occur together and are easily confused. *S. oreophilus* ranges from good to poor timber sites and is nonrhizomatous, forming individual clumps. One- to three-year-old stems have pith-filled centers. *Symphoricarpos albus* occurs only on good sites and is rhizomatous, forming uniform patches or colonies. Its stems have hollow centers. (To check the stems, slice obliquely with a sharp knife on an unbranched section of the main stem.)

SYNECOLOGICAL PERSPECTIVE AND TERMINOLOGY

Definition and Application of Habitat Types

A habitat type is all the land capable of producing similar plant communities at climax (Daubenmire 1968). Because it is the end result of plant succession, the climax plant community reflects the most meaningful integration of the environmental factors affecting vegetation. Each habitat type represents a relatively narrow segment of environmental variation that is delineated by a certain potential for vegetative development. Although one habitat type may support a variety of disturbance-induced or seral plant communities, the ultimate product of vegetative succession anywhere within one habitat type will be similar climax communities. Thus, the habitat type system is a method of site classification that uses the plant community as an integrated indicator of environmental factors as they affect species reproduction, competition, and plant community development.

The climax community type, or association, provides a logical name for the habitat type, for example, *Pseudotsuga menziesii/Calamagrostis rubescens.* The first part of this name is based on the climax tree species, usually the most shade-tolerant tree species adapted to the site. This level of stratification is called the series and encompasses all habitat types having the same dominant tree at climax. The second part of the name is based on the dominant or characteristic undergrowth species in the climax community.

Use of climax community types to name habitat types does not imply that we have an abundance of climax vegetation in the present landscape; actually, most vegetation in the landscape reflects some form of disturbance and various stages of succession towards climax. Furthermore, habitat type names do not imply that we should manage for climax vegetation; in fact, seral species are usually favored for management. In addition, this method does not require the presence of a climax stand to identify the habitat type. It can be identified during most stages of succession by comparing the relative reproductive success of the present tree species with known successional trends and by inspecting the existing undergrowth vegetation. The undergrowth seems to progress more rapidly toward climax than does succession in the tree layer and composition of the undergrowth may become relatively stable soon after the coniferous canopy closes. For stands in very early successional stages, the habitat type can be identified by comparison with adjacent mature stands having similar topographic and edaphic features.

The habitat type classification system has several features that are useful for land and resource management. Habitat types provide a permanent and ecologically based system of land stratification in terms of vegetation potential (Daubenmire 1976). Habitat types also provide a vegetational classification system for near-climax forest communities. Each habitat type encompasses a certain amount of environmental variation, but the variation within a particular habitat type should be less than between types. Thus, plant succession should be predictable for each habitat type and responses to management treatments should be similar on most lands within the same type.

Some Ecologic and Taxonomic Relationships

Certain analogies with systematic botany (plant taxonomy) are useful for conveying the taxonomic and ecologic nature of habitat types. Habitat types (like plant species) have internal variation, thereby complicating identification of individual stands (like individual plants). Closely related habitat types (like plant species) share many characteristics and are distinguished by relatively few characteristics. Individual stands (like individual plants) may display some modal characteristics and some traits transitional to other types (other species), especially along gradual contacts between major climatic, edaphic, or topographic regimes.

Habitat types have geographic distributions and geographic variation (similar to plant species) that follow regional patterns of floristics, climate, and topography. Near the center of their distribution, they may occupy various soils and topographic positions, but at their extremes, they are often restricted to specific topographic positions and substrates. One can even talk of "endemic" and "disjunct" distribution among habitat types. Thus, amount of area occupied by a habitat type varies geographically although the relative position in zonal or topographic sequences usually remains the same.

In developing habitat type taxonomy, total stand characteristics and differential species are both emphasized during initial formulation of the types. Geographic distribution and amplitudes of types are reevaluated more carefully during validation of the preliminary types. Geographic variation and observed local patterns of boundaries between types are both incorporated in finalizing the classification to minimize arbitrary delineation of types.

Selection of differential species to develop and define the classification system requires consideration of their (1) ecologic amplitude and (2) competitive abilities. In order for a species to dominate at climax, it must have a competitive advantage over those species having overlapping amplitudes. Often, this results in a species becoming the climax dominant on sites that are not optimum for that species growth, but these are the sites unfavorable for potential superior competitors. In general, a species becomes a climax dominant between its own environmental limits and the environmental limits of its superior competitors. Some differential species are selected that do not attain climax dominance. However, these species have the capability to persist in the face of competition, thereby becoming useful as indicator species.

Competitive abilities include reproduction, growth, and tolerance during the entire cycle from birth to death. Most of the coniferous tree species reproduce primarily by seed. If seed production and seedbed conditions are adequate, competition is primarily expressed through relative growth rates, shade tolerance, and longevity. Many species in the undergrowth have the capability for vegetative reproduction that often provides an additional competitive advantage. During later successional stages, vegetative reproduction may be a primary factor in maintaining their competitive position. During earlier successional stages, both seed and vegetative reproduction are important to achieve or maintain dominance.

Intergrades exist in any classification system and one must work between extreme concepts of either (1) narrowly defined types with resultant broad ecotones, or (2) broadly defined types with narrow ecotones. One must also choose between a simple system of a few broad types versus numerous narrowly defined types. Our written description of types portrays modal conditions, emphasizing the central characteristics of the type. On the other hand, the key is written in quite specific terms in order to narrow the ecotones for field identification. Therefore, we have tried to achieve a manageable balance between numbers of classified units, natural variation, and application of the taxonomy to field conditions. Some variation is recognized within all habitat types; where possible, phases are defined to reflect major within-type variation.

Use of this taxonomy in field situations requires some judgment in recognizing ecotones because the sequence of types varies from one geographic area to another. For instance, a type may occupy a broad area between two other types in one geographic area, but may be recognizable only as a narrow ecotonal situation in other geographic areas. Scale of mapping and type of management action will influence how these transitional areas are interpreted and displayed. Transitional areas (ecotones) and "hybrid" stands may create some frustration, but can still be mapped as intergrades, referenced to adjacent types, and managed accordingly.

In discussing the relationship of a habitat type to certain environmental features, we have followed the general polyclimax concept of Tansley (1935). Thus, a **climatic climax** is found on deep, loamy soils of gently undulating relief; an **edaphic climax** develops on "abnormal" soils; and a **topographic climax** reflects compensating effects of aspect, or different microclimatic

effect. The **topoedaphic climax** is a convenient way to designate deviation from a climatic climax due to combined effects of soils and topography. Some habitat types are exclusively one type of climax, but most can be found in any category, depending on the interaction of specific environmental features. In the mountainous terrain of Idaho, climatic climax sites are scarce; most stands are influenced strongly by topographic features such as aspect and slope or by edaphic features such as loess or volcanic ash deposits.

Habitat Type Versus Continuum Philosophy

For many years, ecologists who study plant communities have vigorously debated the interpretation of plant-community organization. Although several philosophies have developed, debate often centers on two of them: (1) advocates of typal communities argue that distinct vegetation types develop at climax and reappear across the landscape wherever environmental conditions are similar (Daubenmire 1966); (2) continuum advocates argue that even at climax, vegetation, like environment, varies continuously over the landscape (Cottam and McIntosh 1966; Vogl 1966). Some who accept the typal communities philosophy relate habitat type classifications to the relatively "clear-cut" taxonomic classification of the plant kingdom. Some continuum advocates regard habitat type classifications as an attempt to categorize arbitrary intervals along a complex vegetational continuum. Collier and others (1973) present these contrasting philosophies and advocate an intermediate viewpoint.

While this debate may be of considerable interest academically, it need not preoccupy natural resource managers and field biologists who need a logical, ecologically based environmental classification with which to work. We acknowledge the philosophy that a continuum may exist; nevertheless our objective was to develop a logical classification that reflects the natural patterns found on the landscape. Local conditions that deviate from this classification can still be described in terms of how they differ from typal descriptions presented herein.

THE PHYSICAL SETTING

Vegetation and Climate

Many plants in the Coast and Cascade Mountain Ranges of the Pacific Northwest extend eastward to northern and central Idaho because the environment is moderated by a maritime climate during winter and early spring. During this time, precipitation frequently occurs as prolonged, gentle rainfall interspersed with periods of fog and heavy cloud cover, all of which help moderate temperatures and other conditions for plant growth.

In late spring, the maritime influence diminishes and is replaced by a continental climate (Ross and Savage 1967) that contrasts markedly with the maritime influence. Long intervals of cloudless skies cause warm days and cold nights. Small amounts of precipitation are delivered in brief downpours. On steeper terrain much of this moisture is lost through runoff and daily temperature extremes deter plant growth and even survival. As a result, plant species must tolerate greater summer drought and severely fluctuating temperatures.

Idaho's maritime climate can be visualized as an environmental gradient, with a strong maritime influence in the north that decreases southward and disappears in southeastern portions of central Idaho (Ross and Savage 1967). As a result, many northern Idaho plant species reach their environmental limits within the central Idaho study area.

Although plant species in central Idaho are distributed as a continuum, their potential to dominate communities at climax is not. At climax, *Abies grandis* cannot dominate more shade tolerant *Thuja* and *Tsuga* of northern Idaho. Beyond the environmental limits of these two species, the *Abies* readily dominates until it reaches its own environmental limit farther south. Many undergrowth species react in a similar manner. *Spiraea betulifolia* becomes a climax dominant where it surpasses the limits of *Symphoricarpos albus. Carex geyeri* can dominate beyond the limits of *Calamagrostis rubescens.* Thus a number of species found in small amounts in the north dominate at climax along segments of the environmental gradient farther south.

The north-south gradient is confounded by other gradients having a simultaneous effect. A west-to-east climatic gradient of diminishing maritime influence also exists. Changing elevations and soils add further complexity. Although the north-south climatic gradient often exerts a dominant influence, species reaction to other factors causes different relative amplitudes in different areas. These influences are given careful consideration in this classification.

Physiography

The physiographic provinces in central Idaho have been recently classified and described at the section level (Arnold 1975, unpubl. ref.). Physiographic provinces are broad, relatively homogeneous areas that reflect stratification of similar geologic structure, geomorphic history, and climate. Sections are further refinements of a province using similar criteria and provide framework for describing habitat type distributions. The following province and section descriptions are paraphrased from Arnold (1975, unpubl. ref.):

NORTHERN ROCKY MOUNTAIN PROVINCE

Most of central Idaho occurs in the Northern Rocky Mountain physiographic province, a complex of high, massive mountains dissected by deep valleys. Large-scale folding or faulting creates the basic topography of this province. In some areas, this structural framework has a parallel arrangement of high ridges and broad valleys. Elsewhere it has produced masses of poorly defined mountain ranges with narrow can-

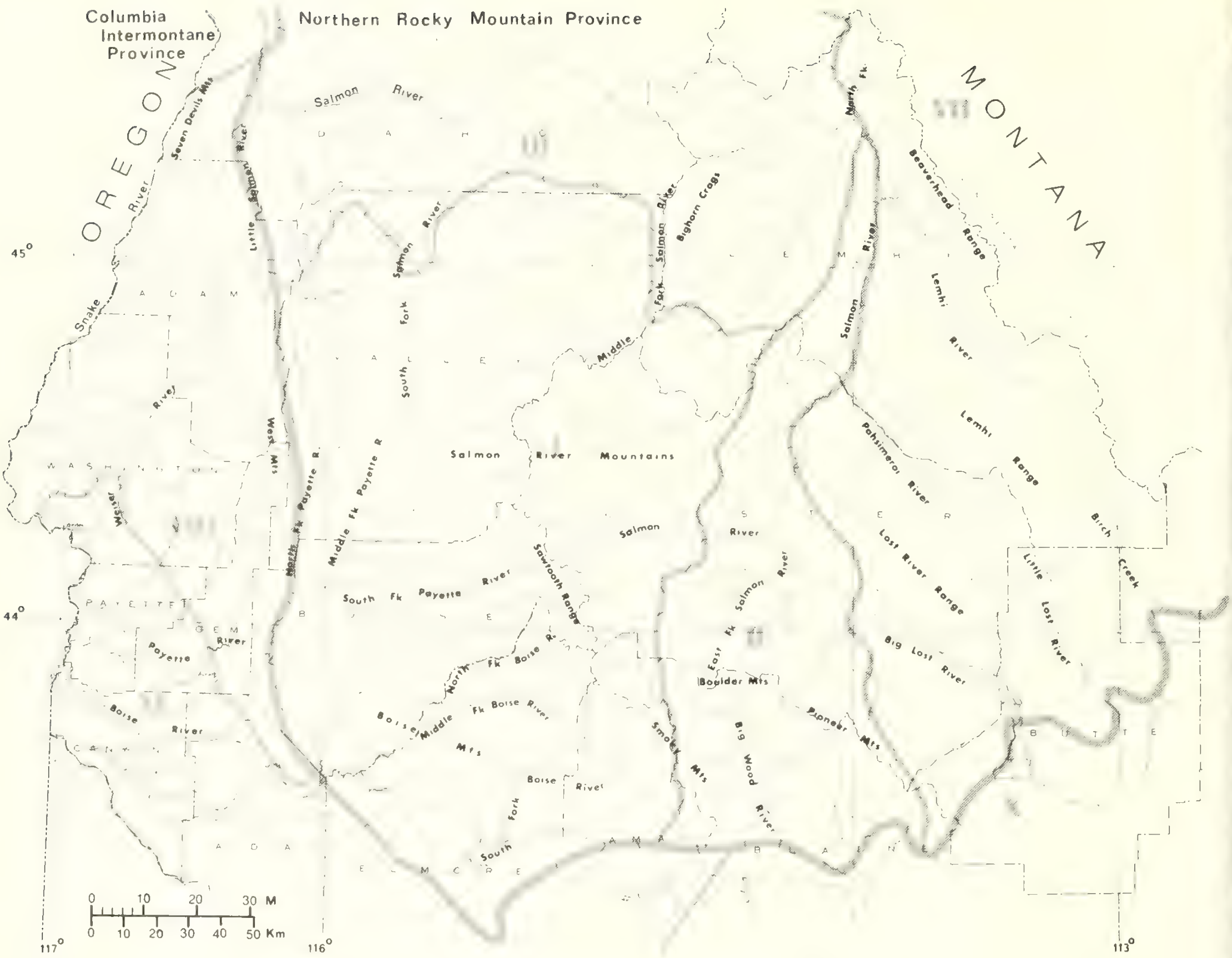


Figure 2. — Physiographic sections of central Idaho (I - Southern Batholith, II - Challis, III - Salmon Uplands, VII - Open Northern Rockies, VIII - Wallowa-Seven Devils).

yons. Granitic rocks of the Idaho batholith underlie much of the central Idaho portion of this province. Precambrian rocks occur under northeastern portions of the area. Volcanic rocks occur in some areas and quaternary and tertiary sediments partially fill many valleys (Ross and Savage 1967). In central Idaho, four sections have been recognized in this province (fig. 2).

Southern Batholith Section (I). — This section delineates the southern lobe of the Idaho batholith and forms the southwestern border of the Northern Rocky Mountain province (I, fig. 2). The Southern Batholith section is drained to the north chiefly by the South and Middle Forks of the Salmon River and to the south by the Boise and Payette Rivers. Elevations range from about 3,000 feet (910 m) to over 10,000 feet (3 050 m) with a median elevation of about 6,500 feet (1 980 m). While the southern batholith contains several rather flat basins (Long Valley, Stanley, Idaho City, Warm Lake, and Deadwood) and some rolling uplands (Landmark Valley and Bear Valley), most of the area has a mountainous relief between 5,000 and 9,000 feet (1 520 and 2 740 m).

Most of the area is underlaid by granitic rocks of the Idaho batholith with some overlying patches of Challis volcanics (mainly in the northeastern portion), some tertiary and quaternary sediments (mostly in the southwestern portion), and even some basalts. Dike swarms of intermediate volcanic character are also common in some areas.

Soils from granitic parent materials occupy more than 80 percent of the section. Such soils are mostly moderately coarse to coarse textured throughout their profiles and are stony in the strongly glaciated, frost-churned areas, and in some depositional conditions. Most soils are deep except on extremely steep slopes, ridges, and headlands. Soils from parent materials other than granite range from sandy loam to predominantly stony.

iis section generally has dry summers and a wet eason from November through March. Most precipita-on during this period is delivered by cyclonic storms om the Pacific Ocean. Precipitation records show verage monthly totals of less than 0.5 inches (1.3 cm) uring July and August, the driest months of the year. verage annual precipitation for the entire section is :.1 inches (81.5 cm) but varies widely; the southern ortion averages less than 15 inches (38.1 cm) a year, hile some high mountain peaks receive more than 60 ches (152.4 cm).

pril 1 snow surveys record the highest water accumu-tion, amounting to 55 to 60 percent of the total an-ual precipitation. Slopes are typically bare below an evation of 4,500 feet (1 370 m) during the winter.

verage annual air temperatures for this section at me-an elevation are: maximum, 46° F (8° C); mean, 36° F ° C); minimum, 22° F (-6° C). The maximum-minimum riation is 24° F or 14° C. This relatively wide mperature variation is due partly to reduced influence Pacific Ocean air masses as compared to more orthern sections of the State. Also, elevational relief thin the section is about 7,000 feet (2 130 m), which n account for about a 23° F or 12° C temperature dif-rence between the lowest and highest areas at any ie time.

hallis Section (II). — The Challis section is an ongated area that extends roughly from Hailey to lmon, Idaho (II, fig. 2). The area is about 40 miles (64 n) wide near Ketchum but only about 5 miles (8 km) de near Salmon. Its western border meets the outhern Batholith section (I) except in the Salmon ver Mountains where it borders the Salmon Uplands ction (III). The Challis section is bounded entirely on e east by the Open Northern Rockies section (IV) and the south by the Columbia Intermontane province.

ie area contains the Boulder-Pioneer-White Cloud anges and Smokey Mountain Range, and eastern opes of the Salmon River Mountains. The wide por-on to the south is drained mainly by the Big Wood, ist Fork of the Salmon, and the headwaters of the Big ost River. On the north the section is drained by a ries of small streams which drain the east slope of e Salmon River Mountains directly into the Main lmon River. Elevations range from about 4,000 feet 220 m) to over 11,500 feet (3 510 m). The median evation is about 7,400 feet (2 260 m).

edrock of the Challis section is largely volcanic and dimentary in origin. Bedrock is composed of an ex-nsive Paleozoic section, large masses of Tertiary lcanics, and some Precambrian rocks (table 1). edrock contains only minor amounts of granitic rock d produces soil and hydrologic features that contrast arkedly to those of the granitic area to the west.

il characteristics vary widely. Table 1 shows the nds of soil textures that can be expected of surface soils and textural B horizons when they are present. Most of the soils derived from quartzite, sandstone, welded tuffs, and basalt are stony as well. Soil depths vary with position on slope, steepness, and dissection.

The north-south orientation and its position just east of a major mountain mass strongly affects the climate of this section. The high mountains to the west and a dominant easterly aspect create a rainshadow over much of the section, allowing only peripheral benefits of winter storms from the Pacific Ocean. Average an-nual precipitation for the entire section is relatively low, only 21.3 inches (54 cm), and ranges from about 7 inches (20 cm) in valleys to over 45 inches (114 cm) on the higher mountains.

Two basic storm patterns affect the Challis section. Low altitude cyclonic storms from the Pacific Ocean move eastward and provide most winter precipitation (November through March). Northern and central por-tions of the Challis section contain mostly easterly slopes and valleys which lie in an effective rainshadow and do not receive full benefit of these storms. The southern portion, however, contains mountains that help offset this rainshadow effect and so receives more winter precipitation. High altitude convectional storms from the Gulf of Mexico and the California Coast move northward and deliver precipitation to both portions of the section in May and June. Thus the southern portion of the section has two wet seasons, a winter (maritime) and a summer (continental), while the northern and cen-tral portions receive only the summer wet season.

As with most snow course data in central Idaho, April 1 surveys in this section generally record the highest water content, amounting to 60 percent of the total an-nual precipitation. May 1 surveys follow closely, with about 50 percent of the total annual precipitation ac-cumulated in snowpack.

The average annual air temperatures for this section at median elevation are: maximum, 49.9° F (10° C); mean, 33.9° F (1° C); and minimum, 18.0° F (-8° C). The main reason for relatively cool temperatures is the high me-dian elevation (7,400 ft, 2 260 m). The reduced Pacific maritime influence and elevational relief (8,000 ft, 2 440 m) within the section creates a maximum-minimum vari-ation of 31.9° F or 18° C. The range in elevation alone can create a 28° F or 15 ° C difference from the lowest to highest areas of the section at any one time.

Salmon Uplands Section (III). — The Salmon Uplands section is roughly bisected by the Salmon River Canyon (III, fig. 2). About 75 percent of the area drains into the Main Salmon River. Less than 5 percent drains into the Bitterroot River and about 20 percent into the Selway River. The western two-thirds of the area shows rem-nants of an uplifted land surface. In the eastern one-third, the old land surface is less evident.

Table 1.--Dominant parent materials and related soil textures of the Challis section (from Arnold 1975, unpubl. ref.)

Parent material		Soil texture (Surface/B horizon)
Paleozoics		
Phyllites		Loams/loams
Dolomites		Silt loams/heavy silt loams
Argillaceous	(siliceous) (calcareous)	Sandy loams/loams
Slates		Silt loams
Conglomerates		Loams
Quartzites		Loamy sands to sandy loams
Limestone		Silt loams/clay loams
Sandstone	(siliceous) (calcareous)	Sandy loams/sandy clay loams
Tertiary volcanics (Challis volcanics)		
Latite-andesite flows	(purple to lavender to brownish)	Loams/heavy loams Loams/clay loams
Basalt	(browns to dark grayish)	Loams/clay loams
Tuffs	(buff colored)	Silt loams/silty clay loams
Welded tuffs		Sandy loams
Rhyolite		Sandy loams
Precambrian rocks - mainly quartzites		

Elevations range from 2,000 to over 10,000 feet (610 to 3 050 m). The canyonlands have relief in excess of 5,000 feet (1 520 m).

The central portion of this area contains mostly granitic rock. "Border Zone" rocks — Precambrian metasediments strongly altered by batholith intrusions — occur on west and north portions of the area. Much of the north-central and east-central portions contain Precambrian metasediments of the Belt Series. Some contacts also occur with Challis volcanics on the south-central and southeastern boundaries and with Columbia River basalts near the northwestern boundary.

Excluding the Salmon River Canyonlands, median elevation of this section is about 7,000 feet (2 130 m). Elevations in these latitudes provide the most southerly evidence of frost churning in the State. In places, frost churning masks remnant deposits from pre-Wisconsin glacial activities.

Near Elk City, at elevations below the frost churning, large areas of Eocene gravel deposits have been mapped. Thick to thin eolian deposits also cover much of the area surrounding Elk City. These deposits rapidly thin south of the Salmon River, but have been identified in the Warm Lake Basin and Bear Valley-Landmark areas to the south. Frost churning has mixed eolian materials to considerable depths in some areas.

Soils are usually deep and overlie highly weathered bedrock materials. Thick soils overlying well-weathered Border Zone rocks high in mica form some of the most massively unstable lands in the area. Thin soils overlying well-weathered granitics are among the highest producers of sediment when subjected to runoff.

Low-altitude storms from the Pacific Coast create wet winters from November through January. High-altitude storms from the Gulf of Mexico and California Coast provide moisture during May and June. The latter wet season often averages greater monthly precipitation than the former; however, the higher elevations probably receive slightly more precipitation during the winter. Annual precipitation for the section averages 31.2 inches (79 cm) and ranges from less than 10 to more than 50 inches (25 to 127 cm), depending on elevation.

Snow surveys record the highest water content on April 1, amounting to 50 to 55 percent of total annual precipitation. Slopes are usually bare below 3,500 feet (1 067 m).

Average annual temperatures for this section at median elevation are: maximum, 50.7° F (10° C); mean, 37.0° F

(3° C); and minimum, 22.4° F (-5° C). Maximum-minimum variation is 28.3° F or 15° C. Elevational relief of about 8,000 feet (2 440 m) can create a 28° F or 15° C) difference at any one time.

Open Northern Rockies Section (VII). — The Idaho portion of this section includes the White Knob Mountains, Lost River and Lemhi Ranges, western slopes of the Beaverhead Range, and intervening valleys (VII, fig. 2). It is drained to the southeast primarily by Birch Creek, Little Lost River, and Big Lost River. To the northwest it is drained mostly by the North Fork of the Salmon, Lemhi, and Pahsimeroi Rivers, and Warm Springs Creek, all of which flow into the Salmon River.

The dominant topography in this section is largely the result of fault block activity. Much of the area displays a lineal basin and range topography typical of the Great Basin. The extreme northern portion has characteristics more similar to the faulted and folded mountains to the northeast. Mountain ranges in this section are among the highest in the State, with numerous peaks above 10,000 feet (3 050 m). Intervening valleys are usually broad and gentle, with base elevations about 5,000 feet (1 520 m).

This section as a whole receives the strongest continental weather patterns in central Idaho. The "wet season" here occurs from May to July and provides 30 to 40 percent of the yearly precipitation, which varies from 7 to 11 inches (18 to 28 cm) in the valleys. This wet cycle results mainly from high altitude convectional storms originating over the Gulf of Mexico and California Coast. Most moisture in low altitude cyclonic storms from the Pacific Ocean is intercepted by numerous mountains to the west. Only extreme northern portions of the section receive partial benefit from the winter storm pattern.

Temperatures are typically cool most of the year, with an annual average at median elevation of about 31.8° F (0° C). The broad intermountain valleys collect considerable cold air, creating severe winter conditions. Cold arctic air lying east of the Continental Divide occasionally invades this section and further lowers winter temperatures.

COLUMBIA INTERMONTANE PROVINCE

The extreme western portion of central Idaho lies in the Columbia Intermontane Province. This area is characterized by numerous sheets of basalt up to several thousand feet thick that surround or abut the higher mountains. These flows occurred periodically from Miocene through Recent, often impounding and then incorporating lake and stream sediments and volcanic ash (Ross and Savage 1967). Part of one section in this province is in west-central Idaho.

Wallowa-Seven Devils Section (Idaho Portion) (VIII). — The Idaho portion of this section (VIII, fig. 2) extends north from Boise to Lucile, Idaho. It is bounded on the south mainly by the Malheur-Boise-King Hill section (XI), on the north by the Tri-State Uplands section (IX), and on the east by the Northern Rocky Mountain province (fig. 2). Hells Canyon forms the western border of the Idaho portion of this section. Elevation ranges from less than 1,500 feet (460 m) in Hells Canyon to over 9,000 feet (2 740 m) in the Seven Devils.

In Idaho, the most extensive rock type in this section is the Columbia River basalts. Older rocks include metamorphosed lavas, sediments, and intrusions of Idaho batholith granitics. The Seven Devils, Cuddy, and Hitt Mountains also contain metamorphic volcanics, sedimentary and intrusive rocks. Younger rocks include sediments of the Payette and Idaho formations in the Boise and Emmett areas.

Block faulting and glacial erosion are common topographic features of this section. Lacustrine and alluvial sediments partially fill some of the down-faulted valleys, particularly at New Meadows, Council, and Horseshoe Bend.

In contrast to eastern sections of the State, this section receives a considerable percentage of its annual precipitation in the winter months. The low elevation cyclonic storms from the Pacific Ocean not only still contain much moisture, but also provide considerable cloud cover and high humidity. This results in moist, moderate winters with few temperature extremes. In spring, the Pacific maritime influence diminishes and clear skies, lower humidity, and variable temperatures prevail during the summer.

Average annual precipitation varies from less than 15 inches to over 45 inches (38 to 114 cm), with runoff ranging from 1 to 30 inches (2 to 76 cm). When the Seven Devils Mountains are excluded, precipitation ranges from less than 15 inches to 40 inches (38 to 102 cm) and the runoff ranges from 1 to 20 inches (2 to 51 cm).

SUCCESSIONAL STATUS OF CENTRAL IDAHO FORESTS

Fire History

As Wellner (1970) noted, fire has burned over most all forest land in the Northern Rocky Mountains at one time or another. There appears, however, to be a trend for fires to occur more often in some areas than others. Over a 5-year period, the Northern Region experienced about three times as many fires from lightning as the Intermountain Region (Barrows 1951). About 89 percent of these fires in the Northern Region occurred west of the Continental Divide. No correlation was found between number of natural fires and critical burning conditions. Instead, a broad lightning zone was recognized across the Clearwater and Nezperce Forests and eastward. This zone, which lies across the northern edge of the central Idaho study area, had more lightning-caused fires than anywhere else in Idaho or Montana.

Western portions of central Idaho also reveal a higher frequency of stand replacing fires than eastern portions. It was notably more difficult to find near-climax stands of closed forest in western and central portions of the area than in the east. The mesic conditions to the west apparently produce more fuels, which may allow greater spread of individual fires. However, frequency of lightning storms may also differ in the two areas enough to be a major factor.

Wellner (1970) suggests that fire has been a natural part of Northern Rocky Mountain ecosystems. Numerous plants including *Pinus monticola, P. contorta, Larix occidentalis,* and *Ceanothus sanguineus* have adapted so well to the effects of repeated burning that much of their present distribution is strongly related to past fires. *Pinus monticola, Larix occidentalis,* and *Ceanothus sanguineus* occur widely in northern Idaho, but become increasingly restricted southward due to unfavorable climate. However, the abundance of seral *Pinus contorta, Ceanothus velutinus,* and *Pinus ponderosa* is often strongly related to fire history in central Idaho.

Though fire frequency may be less in central Idaho than farther north, stand-replacing fires still occur here. In some cases, conflagrations result from dead foliage of trees killed by insect epidemics (Wellner 1970; Hockaday 1968, unpubl. ref.). In other cases, large fires result from unusually dry weather conditions.

Man has caused many of the fires in the Northern Rocky Mountains. Before the white man came, aborigines burned the vegetation for various reasons (DeVoto 1953). Later, prospectors started fires to expose mineral outcrops (Space 1964; unpubl. ref.) and settlers set fires to improve the range (Smith undated, unpubl. ref.). Many of these fires crept into the forest and burned unchecked until extinguished by fall rains. In recent years, some of the most catastrophic fires in central Idaho have been man-caused. According to Barrows (1961), the Intermountain Region had more man-caused fires than the Northern Region during the same period.

Recent studies indicate that low-intensity ground fires were frequent in some parts of the Northern Rocky Mountains prior to the advent of suppression activities in the early 1900's. On the Bitterroot National Forest in western Montana, mean fire-free intervals ranged from 6 to 41 years in different habitat types (Arno 1976). Fire scars were also evident in many central Idaho sample stands, especially at lower elevations. Thus, the composition of many existing stands may reflect the partial influence of one or more ground fires during the life of the stand. The prevalence of *Pinus ponderosa* on many sites within the *Pseudotsuga menziesii* habitat types may reflect these historic fires.

Grazing History

Early grazing by cattle and later by sheep have caused considerable destruction to range and soil resources in central Idaho. The most severe depletion was, and apparently still is, on private and public lands. Here free, unregulated use resulted in forage depletion of more than 50 percent and some areas were estimated at over 75 percent depletion (McArdle and others 1936). Most of the range depleted by cattle was nonforest or open forests at lower elevations.

Range depletion by sheep occurred from lower elevations to the ridges and mountain meadows at upper elevations. Perhaps the most severely abused areas were in the foothills of the Weiser River drainage where one early account (Hockaday 1968, unpubl. ref.) notes soil losses up to 1 foot and a great increase in surface rock. Here several mud-rock and debris floods were attributed to severe overgrazing by sheep. The railhead at Ketchum became the largest shipping point for sheep in the United States (Goodwin and Hussey undated, unpubl. ref.). Sheep trailed into Ketchum from all over central Idaho and elsewhere and so badly overcrowded the Sawtooth Valley that it became almost impossible to graze there. Ten to 20 bands of sheep (up to 3,000 per band) could be commonly seen on the hills above Ketchum awaiting shipping. As a result, the Big Wood River drainage and Sawtooth Valley were severely overgrazed.

By 1903, Idaho had 2.6 million sheep (Stewart 1936), a large percentage of which grazed in central Idaho at least part of the year. Because there were no grazing allotments, sheep men would race herds to choice range in the high country each spring and were then forced to graze one drainage all summer because all other range was occupied (Hockaday 1968, unpubl. ref.; Goodwin and Hussey undated, unpubl. ref.).

On the granitic soils in central Idaho, *Carex geyeri* once formed a dominant ground cover on many sites. In hopes of producing a more palatable forage, sheepherders would destroy the *Carex* swards by trailing their flocks over them (Mont Lewis, USDA Forest Service, retired, personal communication). Other times, just the number of animals in the area destroyed the *Carex*. The results did not always produce more forage and many sites were left exposed to erosion. The *Carex* has only partially recovered but *Artemisia* now partly protects many areas. Artificial revegetation on granitic soils has seen only limited success and rates of natural recovery here are extremely slow.

Today, small bands of sheep still graze the upper ridges and meadows. Cattle graze the densely forested land where they find excellent forage near streams, in natural openings, and in openings created by logging. The widespread grazing abuse of the early 1900's has ended and much of the range is recovering at various rates. Localized damage still may occur where animals congregate. New clearcuts seem especially attractive to livestock; trampling of conifer seedlings and disturbance of soils often outweighs the value of consumed forage.

Logging History

Since arrival of early pioneers, considerable timber has been cut in central Idaho forests. In mineralized areas, prospectors used many logs for construction and fuel and sometimes the land near mining towns was cleared of trees. Early farmers and ranchers often cleared the most fertile forest lands to raise crops and depended on the nearby stands of timber for building materials and fuel. Lumbermen first concentrated on more accessible areas but soon gained access to more remote stands of valuable timber. Access to uncut stands is sought continually so that eventually only very remote areas or those designated for preservation will remain in their natural state. With aerial logging techniques now removing timber once considered impractical to harvest, even small stands of uncut forest may eventually disappear.

Much of the land in central Idaho recovers slowly from logging disturbance, especially in the southern and eastern portions. The clearcut and burn technique of timber management successful farther north has often failed as a tree regeneration method in these areas. Grazing pressure, droughty soils, and low fertility often contribute to the difficulty of reforestation on these sites.

THE HABITAT TYPE CLASSIFICATION

We defined 51 forest habitat types for central Idaho. This large number reflects the range of climatic, geologic, topographic, and floristic diversity of the study area. The total classification (table 2) includes 13 incidental habitat types. To save space, the term "habitat type" is abbreviated "h.t." ("h.t.'s" plural). Frequently used h.t. names in the text are also abbreviated: The first two letters of the genus and the first two letters of the species of the appropriate overstory and undergrowth species make up the taxonomic abbreviation of each h.t. Scientific names of h.t.'s and their abbreviations are listed in table 2. Scientific, abbreviated, and common names of indicator species are listed in the h.t. field form (appendix F). Common names are not used in the text because local variations may be confusing. Initially, our abbreviations may seem awkward, but professional foresters and biologists easily learn them and accept them as a convenient substitute for common names.

The classification is presented in the following order:

1. Key to the habitat types (fig. 3). — To identify the habitat type, one must first carefully read the provided instructions and definitions of terms used in the key. Identification proceeds from climax series to habitat type, and finally to the phase (where appropriate).

2. Series description. — Some h.t. characteristics are summarized at the series level, rather than repeating similarities in each habitat type description.

3. Habitat type description. — This information summarizes geographic range, vegetation, phases, and general management implications.

Arrangement of the h.t.'s within the keys tends to follow a pattern of moderate to severe environments. Species appearing first in the key tend to have the least ecologic amplitude and the greatest importance as indicators in any given series. Thus at the lower elevations, progression through the keys leads one to increasingly drier h.t.'s and at upper elevations it leads one to increasingly colder types. Occasionally this order deviates when habitat types from different geographic areas are merged into one key. Once familiar with the key, awareness of this sequence can help the user identify sites that are difficult to key out.

ble 2.--Forest habitat types of Central Idaho

P de[1]	Abbreviation	Habitat types and phases: Scientific name	Common name	Page number
0		*PINUS FLEXILIS* SERIES		(Refer to Key or Contents)
0	PIFL/HEKI h.t.	*Pinus flexilis/Hesperochloa kingii* h.t.[2]	limber pine/spikefescue	
0	PIFL/FEID h.t.	*Pinus flexilis/Festuca idahoensis* h.t.	limber pine/Idaho fescue	
0	PIFL/CELE h.t.	*Pinus flexilis/Cercocarpus ledifolius* h.t.[2]	limber pine/curl-leaf mountain-mahogany	
0	PIFL/JUCO h.t.	*Pinus flexilis/Juniperus communis* h.t.[2]	limber pine/common juniper	
0		*PINUS PONDEROSA* SERIES		
0	PIPO/STOC h.t.	*Pinus ponderosa/Stipa occidentalis* h.t.	ponderosa pine/western needlegrass	
0	PIPO/AGSP h.t.	*Pinus ponderosa/Agropyron spicatum* h.t.	ponderosa pine/bluebunch wheatgrass	
0	PIPO/FEID h.t.	*Pinus ponderosa/Festuca idahoensis* h.t.	ponderosa pine/Idaho fescue	
0	PIPO/PUTR h.t.	*Pinus ponderosa/Purshia tridentata* h.t.	ponderosa pine/bitterbrush	
1	-AGSP phase	-*Agropyron spicatum* phase	-bluebunch wheatgrass phase	
2	-FEID phase	-*Festuca idahoensis* phase	-Idaho fescue phase	
5	PIPO/SYOR h.t.	*Pinus ponderosa/Symphoricarpos oreophilus* h.t.	ponderosa pine/mountain snowberry	
0	PIPO/SYAL h.t.	*Pinus ponderosa.Symphoricarpos albus* h.t.	ponderosa pine/common snowberry	
0	PIPO/PHMA h.t.	*Pinus ponderosa/Physocarpus malvaceus* h.t.[2]	ponderosa pine/ninebark	

ADP Code[1]	Abbreviation	Habitat types and phases: Scientific name	Common name	Page number
200		***PSEUDOTSUGA MENZIESII* SERIES**		
210	PSME/AGSP h.t.	*Pseudotsuga menziesii/Agropyron spicatum* h.t.	Douglas-fir/bluebunch wheatgrass	
220	PSME/FEID h.t.	*Pseudotsuga menziesii/Festuca idahoensis* h.t.	Douglas-fir/Idaho fescue	
221	-FEID phase	-*Festuca idahoensis* phase	-Idaho fescue phase	
222	-PIPO phase	-*Pinus ponderosa* phase	-ponderosa pine phase	
380	PSME/SYOR h.t.	*Pseudotsuga menziesii/Symphoricarpos oreophilus* h.t.	Douglas-fir/mountain snowberry	
370	PSME/ARCO h.t.	*Pseudotsuga menziesii/Arnica cordifolia* h.t.	Douglas-fir/heartleaf arnica	
372	-ASMI phase	-*Astragalus miser* phase	-weedy milkvetch phase	
371	-ARCO phase	-*Arnica cordifolia* phase	-heartleaf arnica phase	
360	PSME/JUCO h.t.	*Pseudotsuga menziesii/Juniperus communis* h.t.	Douglas-fir/common juniper	
330	PSME/CAGE h.t.	*Pseudotsuga menziesii/Carex geyeri* h.t.	Douglas-fir/elk sedge	
332	-SYOR phase	-*Symphoricarpos oreophilus* phase	-mountain snowberry phase	
334	-PIPO phase	-*Pinus ponderosa* phase	-ponderosa pine phase	
331	-CAGE phase	-*Carex geyeri* phase	-elk sedge phase	
395	PSME/BERE h.t.	*Pseudotsuga menziesii/Berberis repens* h.t.	Douglas-fir/Oregon grape	
397	-SYOR phase	-*Symphoricarpos oreophilus* phase	-mountain snowberry phase	
398	-CAGE phase	-*Carex geyeri* phase	-elk sedge phase	
396	-BERE phase	-*Berberis repens* phase	-Oregon grape phase	
385	PSME/CELE h.t.	*Pseudotsuga menziesii/Cercocarpus ledifolius* h.t.	Douglas-fir/curl-leaf mountain mahogany	
320	PSME/CARU h.t.	*Pseudotsuga menziesii/Calamagrostis rubescens* h.t.	Douglas-fir/pinegrass	
325	-FEID phase	-*Festuca idahoensis* phase	-Idaho fescue phase	
324	-PIPO phase	-*Pinus ponderosa* phase	-ponderosa pine phase	
323	-CARU phase	-*Calamagrostis rubescens* phase	-pinegrass phase	
375	PSME/OSCH h.t.	*Pseudotsuga menziesii/Osmorhiza chilensis* h.t.	Douglas-fir/mountain sweet-root	
340	PSME/SPBE h.t.	*Pseudotsuga menziesii/Spiraea betulifolia* h.t.	Douglas-fir/white spirea	
344	-PIPO phase	-*Pinus ponderosa* phase	-ponderosa pine phase	
343	-CARU phase	-*Calamagrostis rubescens* phase	-pinegrass phase	
341	-SPBE phase	-*Spiraea betulifolia* phase	-white spirea phase	
310	PSME/SYAL h.t.	*Pseudotsuga menziesii/Symphoricarpos albus* h.t.	Douglas-fir/common snowberry	
315	-PIPO phase	-*Pinus ponderosa* phase	-ponderosa pine phase	
313	-SYAL phase	-*Symphoricarpos albus* phase	-common snowberry phase	
280	PSME/VAGL h.t.	*Pseudotsuga menziesii/Vaccinium globulare* h.t.[2]	Douglas-fir/blue huckleberry	
390	PSME/ACGL h.t.	*Pseudotsuga menziesii/Acer glabrum* h.t.	Douglas-fir/mountain maple	
392	-SYOR phase	-*Symphoricarpos oreophilus* phase	-mountain snowberry phase	
393	-ACGL phase	-*Acer glabrum* phase	-mountain maple phase	
200		***PSEUDOTSUGA MENZIESII* SERIES Continued**		
260	PSME/PHMA h.t.	*Pseudotsuga menziesii/Physocarpus malvaceus* h.t.	Douglas-fir/ninebark	
262	-CARU phase	-*Calamagrostis rubescens* phase[2]	-pinegrass phase	
264	-PIPO phase	-*Pinus ponderosa* phase	-ponderosa pine phase	
265	-PSME phase	-*Pseudotsuga menziesii* phase	-Douglas-fir phase	
290	PSME/LIBO h.t.	*Pseudotsuga menziesii/Linnaea borealis* h.t.[2]	Douglas-fir/twinflower	
250	PSME/VACA h.t.	*Pseudotsuga menziesii/Vaccinium caespitosum* h.t.[2]	Douglas-fir/dwarf huckleberry	
400		***PICEA ENGELMANNII* SERIES**		
493	PIEN/HYRE h.t.	*Picea engelmannii/Hypnum revolutum* h.t.	spruce/hypnum	
440	PIEN/GATR h.t.	*Picea engelmannii/Galium triflorum* h.t.[2]	spruce/sweetscented bedstraw	
490	PIEN/CADI h.t.	*Picea engelmannii/Carex disperma* h.t.	spruce/soft leaved sedge	
410	PIEN/EQAR h.t.	*Picea engelmannii/Equisetum arvense* h.t.[2]	spruce/common horsetail	
500		***ABIES GRANDIS* SERIES**		
585	ABGR/CARU h.t.	*Abies grandis/Calamagrostis rubescens* h.t.	grand fir/pinegrass	
505	ABGR/SPBE h.t.	*Abies grandis/Spiraea betulifolia* h.t.	grand fir/white spirea	
515	ABGR/VAGL h.t.	*Abies grandis/Vaccinium globulare* h.t.	grand fir/blue huckleberry	
510	ABGR/XETE h.t.	*Abies grandis/Xerophyllum tenax* h.t.[2]	grand fir/beargrass	
525	ABGR/ACGL h.t.	*Abies grandis/Acer glabrum* h.t.	grand fir/mountain maple	
527	-PHMA phase	-*Physocarpus malvaceus* phase	-ninebark phase	
526	-ACGL phase	-*Acer glabrum* phase	-mountain maple phase	
590	ABGR/LIBO h.t.	*Abies grandis/Linnaea borealis* h.t.	grand fir/twinflower	
593	-VAGL phase	-*Vaccinium globulare* phase	-blue huckleberry phase	
592	-XETE phase	-*Xerophyllum tenax* phase[2]	-beargrass phase	
591	-LIBO phase	-*Linnaea borealis* phase	-twinflower phase	
580	ABGR/VACA h.t.	*Abies grandis/Vaccinium caespitosum* h.t.	grand fir/dwarf huckleberry	
511	ABGR/COOC h.t.	*Abies grandis/Coptis occidentalis* h.t. [2]	grand fir/goldthread	
520	ABGR/CLUN h.t.	*Abies grandis/Clintonia uniflora* h.t.	grand fir/queencup beadlily	

P de[1]	Abbreviation	Habitat types and phases: Scientific name	Common name	Page number
0		***ABIES LASIOCARPA* SERIES**		
5	ABLA/CABI h.t.	*Abies lasiocarpa/Caltha biflora* h.t.	subalpine fir/marsh marigold	
0	ABLA/CACA h.t.	*Abies lasiocarpa/Calamagrostis canadensis* h.t.	subalpine fir/bluejoint	
5	-LEGL phase	-*Ledum glandulosum* phase	-Labrador tea phase	
4	-VACA phase	-*Vaccinium caespitosum* phase	-dwarf huckleberry phase	
2	-LICA phase	-*Ligusticum canbyi* phase	-Canby's ligusticum phase	
1	-CACA phase	-*Calamagrostis canadensis* phase	-bluejoint phase	
5	ABLA/STAM h.t.	*Abies lasiocarpa/Streptopus amplexifolius* h.t.	subalpine fir/twisted stalk	
7	-LICA phase	-*Ligusticum canbyi* phase	-Canby's ligusticum phase	
6	-STAM phase	-*Streptopus amplexifolius* phase	-twisted stalk phase	
0	ABLA/CLUN h.t.	*Abies lasiocarpa/Clintonia uniflora* h.t.	subalpine fir/queencup beadlily	
5	-MEFE phase	-*Menziesia ferruginea* phase[2]	-menziesia phase	
1	-CLUN phase	-*Clintonia uniflora* phase	-queencup beadlily	
8	ABLA/COOC h.t.	*Abies lasiocarpa/Coptis occidentalis* h.t.[2]	subalpine fir/goldthread	
0	ABLA/MEFE h.t.	*Abies lasiocarpa/Menziesia ferruginea* h.t.	subalpine fir/menziesia	
2	-LUHI phase	-*Luzula hitchcockii* phase[2]	-smooth woodrush phase	
1	-MEFE phase	-*Menziesia ferruginea* phase	-menziesia phase	
5	ABLA/ACGL h.t.	*Abies lasiocarpa/Acer glabrum* h.t.	subalpine fir/mountain maple	
0	ABLA/VACA	*Abies lasiocarpa/Vaccinium caespitosum* h.t.	subalpine fir/dwarf huckleberry	
0	ABLA/LIBO h.t.	*Abies lasiocarpa/Linnaea borealis* h.t.	subalpine fir/twinflower	
1	-LIBO phase	-*Linnaea borealis* phase	-twinflower phase	
2	-XETE phase	-*Xerophyllum tenax* phase[2]	-beargrass phase	
3	-VASC phase	-*Vaccinium scoparium* phase[2]	-grouse whortleberry phase	
0	ABLA/ALSI h.t.	*Abies lasiocarpa/Alnus sinuata* h.t.[2]	subalpine fir/Sitka alder	
00		***ABIES LASIOCARPA* SERIES Continued**		
90	ABLA/XETE h.t.	*Abies lasiocarpa/Xerophyllum tenax* h.t.	subalpine fir/beargrass	
91	-VAGL	-*Vaccinium globulare* phase	-blue huckleberry phase	
92	-VASC phase	-*Vaccinium scoparium* phase	-grouse whortleberry phase	
94	-LUHI phase	-*Luzula hitchcockii* phase	-smooth woodrush phase	
20	ABLA/VAGL h.t.	*Abies lasiocarpa/Vaccinium globulare* h.t.	subalpine fir/blue huckleberry	
23	-VAGL phase	-*Vaccinium globulare* phase	-blue huckleberry phase	
21	-VASC phase	-*Vaccinium scoparium* phase[2]	-grouse whortleberry phase	
05	ABLA/SPBE h.t.	*Abies lasiocarpa/Spiraea betulifolia* h.t.	subalpine fir/white spirea	
30	ABLA/LUHI h.t.	*Abies lasiocarpa/Luzula hitchcockii* h.t.	subalpine fir/smooth woodrush	
31	-VASC phase	-*Vaccinium scoparium* phase	-grouse whortleberry phase	
33	-LUHI phase	-*Luzula hitchcockii* phase	-smooth woodrush phase	
30	ABLA/VASC h.t.	*Abies lasiocarpa/Vaccinium scoparium* h.t.	subalpine fir/grouse whortleberry	
31	-CARU phase	-*Calamagrostis rubescens* phase	-pinegrass phase	
32	-VASC phase	-*Vaccinium scoparium phase*	-grouse whortleberry phase	
34	-PIAL phase	-*Pinus albicaulis* phase	-whitebark pine phase	
50	ABLA/CARU h.t.	*Abies lasiocarpa/Calamagrostis rubescens* h.t.	subalpine fir/pinegrass h.t.	
90	ABLA/CAGE h.t.	*Abies lasiocarpa/Carex geyeri* h.t.	subalpine fir/elk sedge h.t.	
91	-CAGE phase	-*Carex geyeri* phase	-elk sedge phase	
93	-ARTR phase	-*Artemisia tridentata* phase	-big sagebrush phase	
45	ABLA/JUCO h.t.	*Abies lasiocarpa/Juniperus communis* h.t.	subalpine fir/common juniper	
10	ABLA/RIMO h.t.	*Abies lasiocarpa/Ribes montigenum* h.t.	subalpine fir/mountain gooseberry	
30	ABLA/ARCO h.t.	*Abies lasiocarpa/Arnica cordifolia* h.t.	subalpine fir/heartleaf arnica	
50	PIAL-ABLA h.t.s.	*Pinus albicaulis-Abies lasiocarpa* h.t.s.	whitebark pine-subalpine fir	
70		***PINUS ALBICAULIS* SERIES**		
70	PIAL h.t.s.	*Pinus albicaulis* h.t.s.	whitebark pine	
00		***PINUS CONTORTA* SERIES**		
20	PICO/VACA	*Pinus contorta/Vaccinium caespitosum* c.t.[2]	lodgepole pine/dwarf huckleberry	
40	PICO/VASC	*Pinus contorta/Vaccinium scoparium* c.t.[2]	lodgepole pine/grouse whortleberry	
55	PICO/CAGE	*Pinus contorta/Carex geyeri* c.t.[2]	lodgepole pine/elk sedge	
05	PICO/FEID	*Pinus contorta/Festuca idahoensis* h.t.	lodgepole pine/Idaho fescue	

otal number of habitat types = 64 (includes 13 incidental h.t.'s and 22 h.t.'s with defined phases).
otal number of phases = 55 (includes 7 incidental phases).
otal number of *Pinus contorta* community types = 3.
otal number of categories at lowest level of hierarchy = 100 (includes 20 incidental h.t.'s and phases).

Automatic data processing codes.

Incidental habitat types, phases or community types in central Idaho; not listed in other charts and tables.

Figure 3.-- Key to climax series, habitat types, and phases.

READ THESE INSTRUCTIONS FIRST!

1. Use this key for stands with a mature tree canopy that are not severely disturbed by grazing, logging, forest fire, etc. (If the stand is severely disturbed or in an early successional stage, the habitat type can best be determined by extrapolating from the nearest mature stand occupying a similar site.)

2. Accurately identify and record canopy coverages for all indicator species (appendix F).

3. Check plot data in the field to verify that the plot is representative of the stand as a whole. If not, take another plot.

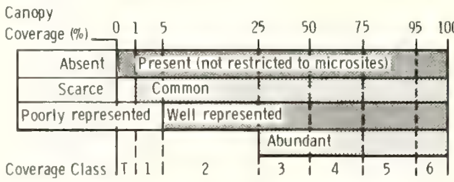
4. Identify the correct potential climax tree species in the SERIES key. (Generally, a tree species is considered reproducing successfully if 10 or more individuals per acre occupy or will occupy the site.)

5. Within the appropriate series, key to HABITAT TYPE by following the key literally. Determine PHASE by matching the stand conditions with the phase descriptions for the type. (The first phase description that fits the stand is the correct one.)

6. Use the definitions diagramed below for canopy coverage terms in the key. If you have difficulty deciding between types, refer to constancy and coverage data (appendix C-1) and the habitat type descriptions.

7. In stands where undergrowth is obviously depauperate (unusually sparse) because of dense shading or duff accumulations, adjust the above definitions to the next lower coverage class (e.g., well represented >1%, common >0%).

8. Remember, the key is NOT the classification! Validate the determination made using the key by checking the written description.



KEY TO CLIMAX SERIES

(Do Not Proceed Until You Have Read The Instructions)

1. Abies grandis present and reproducing more successfully than Abies lasiocarpa . . . . ABIES GRANDIS SERIES (item E)
1. Abies grandis not the indicated climax 2

  2. Abies lasiocarpa present and reproducing successfully . . . . ABIES LASIOCARPA SERIES (item G)
  2. Abies lasiocarpa not the indicated climax 3

3. Picea engelmannii present and reproducing successfully . . . . PICEA ENGELMANNII SERIES (item D)
3. Picea engelmannii not the indicated climax 4

  4. Pinus flexilis a successfully reproducing dominant in old growth stands; often sharing that status with Pseudotsuga . . . . PINUS FLEXILIS SERIES (item A)
  4. Pinus flexilis absent or clearly seral 5

5. Pseudotsuga menziesii present and reproducing successfully . . . . PSEUDOTSUGA MENZIESII SERIES (item C)
5. Pseudotsuga menziesii not the indicated climax 6

  6. Pinus albicaulis well represented and reproducing successfully . . . . PINUS ALBICAULIS SERIES (p. 82)
  6. Pinus albicaulis not the indicated successional dominant 7

7. Pinus contorta dominant and reproducing successfully . . . . PINUS CONTORTA SERIES (item F)
7. Pinus contorta not the indicated successional dominant 8

  8. Pinus ponderosa present and reproducing successfully . . . . PINUS PONDEROSA SERIES (item B)
  8. Pinus ponderosa not the indicated climax 9

9. Populus tremuloides the indicated dominant . . . . POPULUS TREMULOIDES SERIES (p. 87)
9. Populus tremuloides not the indicated dominant . . . . Minor forest types (p. 87)

A. Key to Pinus flexilis Habitat Types

1. Juniperus communis well represented . . . . PINUS FLEXILIS/JUNIPERUS COMMUNIS h.t.* (p. 22)
1. J. communis poorly represented 2

  2. Cercocarpus ledifolius is well represented . . . . PINUS FLEXILIS/CERCOCARPUS LEDIFOLIUS h.t.* (p. 22)
  2. C. ledifolius poorly represented 3

3. Festuca idahoensis well represented . . . . PINUS FLEXILIS/FESTUCA IDAHOENSIS h.t. (p. 20)
3. F. idahoensis poorly represented, Hesperochloa kingii (Leucopoa kingii) common . . . . PINUS FLEXILIS/HESPEROCHLOA KINGII* h.t. (p. 20)

B. Key to Pinus ponderosa Habitat Types

1. Physocarpus malvaceus well represented . . . . PINUS PONDEROSA/PHYSOCARPUS MALVACEUS h.t.* (p. 29)
1. P. malvaceus poorly represented 2

  2. Symphoricarpos albus well represented . . . . PINUS PONDEROSA/SYMPHORICARPOS ALBUS H.T. (p. 28)
  2. S. albus poorly represented 3

3. Symphoricarpos oreophilus or Prunus virginiana well represented . . . . PINUS PONDEROSA/SYMPHORICARPOS OREOPHILUS h.t. (p. 27)
3. S. oreophilus and P. virginiana poorly represented 4

  4. Purshia tridentata well represented . . . . PINUS PONDEROSA/PURSHIA TRIDENTATA h.t. (p. 26)
    4a. Festuca idahoensis well represented . . . . FESTUCA IDAHOENSIS phase
    4b. F. idahoensis poorly represented . . . . AGROPYRON SPICATUM phase
  4. P. tridentata poorly represented 5

5. Festuca idahoensis well represented . . . . PINUS PONDEROSA/FESTUCA IDAHOENSIS h.t. (p. 25)
5. F. idahoensis poorly represented 6

  6. Agropyron spicatum well represented on sites in good condition . . . . PINUS PONDEROSA/AGROPYRON SPICATUM h.t. (p. 24)
  6. A. spicatum poorly represented on sites in good condition and Stipa spp. well represented . . . . PINUS PONDEROSA/STIPA OCCIDENTALIS h.t. (p. 24)

*h.t.s and phases incidental to central Idaho and omitted from charts and tables.

C. Key to Pseudotsuga menziesii Habitat Types

1. Vaccinium caespitosum common . . . . . PSEUDOTSUGA MENZIESII/VACCINIUM CAESPITOSUM h.t.* (p. 46)
1. V. caespitosum scarce 2

2. Linnaea borealis common . . . . . PSEUDOTSUGA MENZIESII/LINNAEA BOREALIS h.t.* (p. 46)
2. L. borealis scarce 3

3. Physocarpus malvaceus and/or Holodiscus discolor well represented . . . PSEUDOTSUGA MENZIESII/PHYSOCARPUS MALVACEUS h.t. (p. 44)
   3a. Pinus ponderosa present or potentially present
      a. Calmagrostis rubescens and/or Carex geyeri dominant; Physocarpus forming only a broken, patchy cover . . . . . CALAMAGROSTIS RUBESCENS phase*
      b. Not as above . . . . . PINUS PONDEROSA phase
   3b. P. ponderosa absent and unable to establish . . . . . PSEUDOTSUGA MENZIESII phase
3. P. malvaceus and H. discolor poorly represented 4

4. Acer glabrum well represented . . . . . PSEUDOTSUGA MENZIESII/ACER GLABRUM h.t. (p. 43)
   4a. Penstemon wilcoxii and/or Clematis columbiana usually present; sites mainly west of the Big Wood River . . . . . ACER GLABRUM phase
   4b. Pinus flexilis usually present, sites mainly east of the Big Wood River . . . . . SYMPHORICARPOS OREOPHILUS phase
4. A. glabrum poorly represented 5

5. Vaccinium globulare or Xerophyllum tenax well represented . . . . . PSEUDOTSUGA MENZIESII/VACCINIUM GLOBULARE h.t.* (p. 43)
5. V. globulare and X. tenax poorly represented 6

6. Symphoricarpos albus well represented . . . . . PSEUDOTSUGA MENZIESII/SYMPHORICARPOS ALBUS h.t. (p. 42)
   6a. Pinus ponderosa present or potentially present . . . . . PINUS PONDEROSA phase
   6b. P. ponderosa absent and unable to establish . . . . . SYMPHORICARPOS ALBUS phase
6. S. albus poorly represented 7

7. Spiraea betulifolia or S. pyramidata well represented . . . . . PSEUDOTSUGA MENZIESII/SPIRAEA BETULIFOLIA h.t. (p. 40)
   7a. Pinus ponderosa present or potentially present . . . . . PINUS PONDEROSA phase
   7b. Calamagrostis rubescens well represented . . . . . CALAMAGROSTIS RUBESCENS phase
   7c. Not as above in 7a or 7b . . . . . SPIRAEA BETULIFOLIA phase
7. S betulifolia and S. pyramidata poorly represented 8

8. Osmorhiza chilensis well represented . . . . . PSEUDOTSUGA MENZIESII/OSMORHIZA CHILENSIS h.t. (p. 40)
8. O. chilensis poorly represented 9

9. Calamagrostis rubescens well represented . . . . . PSEUDOTSUGA MENZIESII/CALAMAGROSTIS RUBESCENS h.t. (p. 38)
   9a. Pinus ponderosa present or potentially present . . . . . PINUS PONDEROSA phase
   9b. P. ponderosa absent and unable to establish; Festuca iahoensis well represented . . . . . FESTUCA IDAHOENSIS phase
   9c. Not as above in 9a or 9b . . . . . CALAMAGROSTIS RUBESCENS phase
9. C. rubescens poorly represented 10

10. Cercocarpus ledifolius well represented and the indicated climax dominant shrub . . . . . PSEUDOTSUGA MENZIESII/CERCOCARPUS LEDIFOLIUS h.t. (p. 38)
10. C. ledifolius poorly represented or seral 11

11. Berberis repens well represented . . . . . PSEUDOTSUGA MENZIESII/BERBERIS REPENS h.t. (p. 36)
   11a. Carex geyeri abundant . . . . . CAREX GEYERI phase
   11b. C. geyeri not abundant, Symphoricarpos oreophilus abundant, stands never achieving closed canopies . . . . . SYMPHORICARPOS OREOPHILUS phase
   11c. S. oreophilus not abundant, stands eventually achieving closed canopies . . . . . BERBERIS REPENS phase
11. B. repens poorly represented 12

12. Carex geyeri well represented . . . . . PSEUDOTSUGA MENZIESII/CAREX GEYERI h.t. (p. 35)
   12a. Pinus ponderosa present or potentially present . . . . . PINUS PONDEROSA phase
   12b. P. ponderosa absent and unable to establish; Symphoricarpos oreophilus or Artemisia tridentata well represented . . . . . SYMPHORICARPOS OREOPHILUS phase
   12c. Not as above in 12a or 12b . . . . . CAREX GEYERI phase
12. C. geyeri poorly represented 13

13. Juniperus communis well represented . . . . . PSEUDOTSUGA MENZIESII/JUNIPERUS COMMUNIS h.t. (p. 34)
13. J. communis poorly represented 14

14. Arnica cordifolia or Astragalus miser well represented or a dominant forb of normally depauperate undergrowths . . . . . PSEUDOTSUGA MENZIESII/ARNICA CORDIFOLIA h.t. (p. 33)
   14a. Arnica cordifolia well represented . . . . . ARNICA CORDIFOLIA phase
   14b. A. cordifolia poorly represented; Astragalus miser well represented . . . . . ASTRAGALUS MISER phase
14. A. cordifolia and A. miser poorly represented or not a dominant forb 15

15. Symphoricarpos oreophilus, Ribes cereum or Prunus virginiana well represented . . . . . PSEUDOTSUGA MENZIESII/SYMPHORICARPOS OREOPHILUS h.t. (p. 32)
15. S. oreophilus, R. cereum and P. virginiana poorly represented 16

16. Festuca idahoensis well represented . . . . . PSEUDOTSUGA MENZIESII/FESTUCA IDAHOENSIS h.t. (p. 31)
   16a. Pinus ponderosa present . . . . . PINUS PONDEROSA phase
   16b. P. ponderosa absent . . . . . FESTUCA IDAHOENSIS phase
16. F. idahoensis poorly represented; Agropyron spicatum or Melica bulbosa well represented on sites in good condition . . . . . PSEUDOTSUGA MENZIESII/AGROPYRON SPICATUM h.t. (p. 30)

D. Key to Picea engelmannii Habitat Types

1. Equisetum arvense abundant . . . . . PICEA ENGELMANNII/EQUISETUM ARVENSE h.t.* (p. 49)
1. E. arvense not abundant 2

2. Carex disperma well represented . . . . . PICEA ENGELMANNII/CAREX DISPERMA h.t. (p. 47)
2. C. disperma poorly represented 3

3. Galium triflorum, Actaea rubra or Streptopus amplexifolius common either individually or collectively . . . . . PICEA ENGELMANNII/GALIUM TRIFLORUM h.t.* (p. 47)
3. Not as above, Hypnum revolutum (a prostrate moss) well represented . . . . . PICEA ENGELMANNII/HYPNUM REVOLUTUM h.t. (p. 47)

*h.t.s and phases incidental to central Idaho and omitted from charts and tables.

E. Key to Abies grandis Habitat Types

1. Clintonia uniflora present	ABIES GRANDIS/CLINTONIA UNIFLORA h.t. (p. 58)
1. C. uniflora absent	2
2. Coptis occidentalis common	ABIES GRANDIS/COPTIS OCCIDENTALIS h.t.* (p. 58)
2. C. occidentalis scarce	3
3. Vaccinium caespitosum common	ABIES GRANDIS/VACCINIUM CAESPITOSUM h.t. (p. 56)
3. V. caespitosum scarce	4
4. Linnaea borealis common	ABIES GRANDIS/LINNAEA BOREALIS h.t. (p. 54)
4a. Xerophyllum tenax common	XEROPHYLLUM TENAX phase*
4b. X. tenax scarce; Vaccinium globulare well represented	VACCINIUM GLOBULARE phase
4c. Not as above in 4a or 4b	LINNAEA BOREALIS phase
4. L. borealis scarce	5
5. Acer glabrum, Physocarpus malvaceus or Holodiscus discolor well represented. If only common then Adenocaulon bicolor or Disporum trachycarpum present	ABIES GRANDIS/ACER GLABRUM h.t. (p. 54)
5a. Acer glabrum well represented; if only common then at least more prevalent than Physocarpus and Holodiscus	ACER GLABRUM phase
5b. A. glabrum poorly represented and less prevalent than Physocarpus and Holodiscus	PHYSOCARPUS MALVACEUS phase
5. Not as above	6
6. Xerophyllum tenax well represented	ABIES GRANDIS/XEROPHYLLUM TENAX h.t. * (p. 53)
6. X. tenax poorly represented	7
7. Vaccinium globulare well represented	ABIES GRANDIS/VACCINIUM GLOBULARE h.t. (p. 52)
7. V. globulare poorly represented	8
8. Spiraea betulifolia or Lathyrus nevadensis well represented	ABIES GRANDIS/SPIRAEA BETULIFOLIA h.t. (p. 52)
8. S. betulifolia and L. nevadensis poorly represented; Calamagrostis rubescens well represented	ABIES GRANDIS/CALAMAGROSTIS RUBESCENS h.t. (p. 50)

F. Key to Pinus contorta communities

1. Calamagrostis canadensis or Ledum glandulosum well represented	ABIES LASIOCARPA/CALAMAGROTIS CANADENSIS h.t. (p. 61)
1. C. canadensis and L. glandulosum poorly represented	2
2. Streptopus amplexifolius, Senecio triangularis, Ligusticum canbyi or Trautvetteria caroliniensis well represented either individually or collectively	ABIES LASIOCARPA/STREPTOPUS AMPLEXIFOLIUS h.t. (p. 61)
2. Not as above	3
3. Clintonia uniflora present	ABIES LASIOCARPA/CLINTONIA UNIFLORA h.t. (p. 61)
3. C. uniflora absent	4
4. Coptis occidentalis common	ABIES LASIOCARPA/COPTIS OCCIDENTALIS h.t.* (p. 65) or ABIES GRANDIS/COPTIS OCCIDENTALIS h.t.* (p. 58)
4. C. occidentalis scarce	5
5. Menziesia ferruginea well represented	ABIES LASIOCARPA/MENZIESIA FERRUGINEA h.t.(p. 66)
5. M. ferruginea poorly represented	6
6. Vaccinium caespitosum common	PINUS CONTORTA/VACCINIUM CAESPITOSUM c.t. (p. 84)
6. V. caespitosum scarce	7
7. Linnaea borealis common	ABIES LASIOCARPA/LINNAEA BOREALIS h.t. (p. 68) or ABIES GRANDIS/LINNAEA BOREALIS h.t. (p. 54)
7. L. borealis scarce	8
8. Alnus sinuata well represented	ABIES LASIOCARPA/ALNUS SINUATA h.t.* (p. 69)
8. A. sinuata poorly represented	9
9. Xerophyllum tenax well represented	ABIES LASIOCARPA/XEROPHYLLUM TENAX h.t. (p. 69) or ABIES GRANDIS/XEROPHYLLUM TENAX h.t. (p. 53)
9. X. tenax poorly represented	10
10. Vaccinium globulare well represented	ABIES LASIOCARPA/VACCIMIUM GLOBULARE h.t. (p. 70) or ABIES GRANDIS/VACCINIUM GLOBULARE h.t. (p. 52)
10. V. globulare poorly represented	11
11. Spiraea betulifolia well represented	ABIES LASIOCARPA/SPIRAEA BETULIFOLIA h.t. (p. 72) or PSEUDOTSUGA MENZIESII/SPIRAEA BETULIFOLIA h.t. (p. 40)
11. S. betulifolia poorly represented	12
12. Luzula hitchcockii common	ABIES LASIOCARPA/LUZULA HITCHCOCKII h.t. (p. 72)
12. L. hitchcockii scarce	13
13. Vaccinium scoparium well represented	PINUS CONTORTA/VACCINIUM SCOPARIUM c.t. (p. 85)
13. V. scoparium poorly represented	14
14. Calamagrostis rubescens well represented	ABIES LASIOCARPA/CALAMAGROSTIS RUBESCENS h.t. (p. 76) or PSEUDOTSUGA MENZIESII/CALAMAGROSTIS RUBESCENS h.t. (p. 38)
14. C. rubescens poorly represented	15
15. Carex geyeri well represented	PINUS CONTORTA/CAREX GEYERI c.t. (p. 85)
15. C. geyeri poorly represented	16
16. Juniperus communis well represented	ABIES LASIOCARPA/JUNIPERUS COMMUNIS h.t. (p. 78) or PSEUDOTSUGA MENZIESII/JUNIPERUS COMMUNIS h.t. (p. 34)
16. J. communis poorly represented	17
17. Arnica cordifolia well represented or the dominant forb of normally depauperate undergrowths	ABIES LASIOCARPA/ARNICA CORDIFOLIA h.t. (p. 79) or PSEUDOTSUGA MENZIESII/ARNICA CORDIFOLIA h.t. (p. 33)
17. Not as above; Festuca idahoensis common	PINUS CONTORTA/FESTUCA IDAHOENSIS h.t. (p. 85)

*h.t.s and phases incidental to central Idaho and omitted from charts and tables

G. Key to *Abies lasiocarpa* Habitat Types

1. *Caltha biflora* common	ABIES LASIOCARPA/CALTHA BIFLORA h.t. (p. 59)
1. *C. biflora* scarce	2
2. *Equisetum arvense* abundant	PICEA ENGELMANNII/EQUISETUM ARVENSE h.t.* (p. 49)
2. *E. arvense* not abundant	3
3. *Carex disperma* well represented	PICEA ENGELMANNII/CAREX DISPERMA h.t. (p. 47)
3. *C. disperma* poorly represented	4
4. *Calamagrostis canadensis* or *Ledum glandulosum* well represented	ABIES LASIOCARPA/CALAMAGROSTIS CANADENSIS h.t. (p. 61)
4a. *Ledum glandulosum* well represented	LEDUM GLANDULOSUM phase
4b. Not as above in 4a; *Vaccinium caespitosum* common	VACCINIUM CAESPITOSUM phase
4c. Not as above in 4a or 4b; *Ligusticum canbyi* or *Trautvetteria caroliniensis* present	LIGUSTICUM CANBYI phase
4d. Not as above in 4a, 4b, or 4c	CALAMAGROSTIS CANADENSIS phase
4. *C. canadensis* and *L. glandulosum* poorly represented	5
5. *Streptopus amplexifolius*, *Senecio triangularis*, *Ligusticum canbyi* or *Trautvetteria caroliniensis* well represented either individually or collectively	ABIES LASIOCARPA/STREPTOPUS AMPLEXIFOLIUS h.t. (p. 61)
5a. *Ligusticum canbyi* or *Trautvetteria caroliniensis* present	LIGUSTICUM CANBYI phase
5b. *L. canbyi* and *T. caroliniensis* absent	STREPTOPUS AMPLEXIFOLIUS phase
5. Not as above	6
6. *Clintonia uniflora* present	ABIES LASIOCARPA/CLINTONIA UNIFLORA h.t. (p. 65)
6a. *Menziesia ferruginea* well represented	MENZIESIA FERRUGINEA phase*
6b. *M. ferruginea* poorly represented	CLINTONIA UNIFLORA phase
6. *C. uniflora* absent	7
7. *Coptis occidentalis* common	ABIES LASIOCARPA/COPTIS OCCIDENTALIS h.t.* (p. 65)
7. *C. occidentalis* scarce	8
8. *Menziesia ferruginea* well represented	ABIES LASIOCARPA/MENZIESIA FERRUGINEA h.t. (p. 65)
8a. *Luzula hitchcockii* common	LUZULA HITCHCOCKII phase*
8b. *L. hitchcockii* scarce	MENZIESIA FERRUGINEA phase
8. *M. ferruginea* poorly represented	9
9. *Acer glabrum* well represented	ABIES LASIOCARPA/ACER GLABRUM h.t. (p. 67)
9. *A. glabrum* poorly represented	10
10. *Vaccinium caespitosum* common	ABIES LASIOCARA/VACCINIUM CAESPITOSUM h.t. (p. 67)
10. *V. caespitosum* scarce	11
11. *Linnaea borealis* common	ABIES LASIOCARPA/LINNAEA BOREALIS h.t. (p. 68)
11a. *Xerophyllum tenax* well represented	XEROPHYLLUM TENAX phase*
11b. *X. tenax* poorly represented; *Vaccinium scoparium* well represented	VACCINIUM SCOPARIUM phase*
11c. Not as above in 11a or 11b	LINNAEA BOREALIS phase
11. *L. borealis* scarce	12
12. *Alnus sinuata* well represented	ABIES LASIOCARPA/ALNUS SINUATA h.t.* (p. 69)
12. *A. sinuata* poorly represented	13
13. *Xerophyllum tenax* well represented	ABIES LASIOCARPA/XEROPHYLLUM TENAX h.t. (p. 69)
13a. *Vaccinium globulare* or *Spiraea betulifolia* well represented	VACCINIUM GLOBULARE phase
13b. Not as above in 13a; *Luzula hitchcockii* common	LUZULA HITCHCOCKII phase
13c. Not as above in 13a or 13b; *Vaccinium scoparium* usually abundant	VACCINIUM SCOPARIUM phase*
13. *X. tenax* poorly represented	14
14. *Vaccinium globulare* well represented	ABIES LASIOCARPA/VACCINIUM GLOBULARE h.t. (p. 70)
14a. *Vaccinium scoparium* abundant	VACCINIUM SCOPARIUM phase*
14b. *V. scoparium* not abundant	VACCINIUM GLOBULARE phase
14. *V. globulare* poorly represented	15
15. *Spiraea betulifolia* well represented	ABIES LASIOCARPA/SPIRAEA BETULIFOLIA h.t. (p. 72)
15. *S. betulifolia* poorly represented	16
16. *Luzula hitchcockii* common	ABIES LASIOCARPA/LUZULA HITCHCOCKII h.t. (p. 72)
16a. *Vaccinium scoparium* well represented	VACCINIUM SCOPARIUM phase
16b. Not as above in 16a, *Luzula hitchcockii* well represented	LUZULA HITCHCOCKII phase
16c. Not as above in 16a or 16b	22
16. *L. hitchcockii* scarce	17
17. *Vaccinium scoparium* well represented	ABIES LASIOCARPA/VACCINIUM SCOPARIUM h.t. (p. 74)
17a. *Calamagrostis rubescens* well represented	CALAMAGROSTIS RUBESCENS phase
17b. Not as above in 17a; *Pinus albicaulis* well represented	PINUS ALBICAULIS phase
17c. Not as above in 17a or 17b	VACCINIUM SCOPARIUM phase
17. *V. scoparium* poorly represented	18
18. *Calamagrostis rubescens* well represented	ABIES LASIOCARPA/CALAMAGROSTIS RUBESCENS h.t. (p. 76)
18. *C. rubescens* poorly represented	19
19. *Carex geyeri* well represented	ABIES LASIOCARPA/CAREX GEYERI h.t. (p. 76)
19a. *Artemisia tridentata* well represented	ARTEMISIA TRIDENTATA phase
19b. *A. tridentata* poorly represented	CAREX GEYERI phase
19. *C. geyeri* poorly represented	20
20. *Juniperus communis* well represented	ABIES LASIOCARPA/JUNIPERUS COMMUNIS h.t. (p. 78)
20. *J. communis* poorly represented	21
21. *Ribes montigenum* well represented or the dominant plant of normally depauperate undergrowths	ABIES LASIOCARPA/RIBES MONTIGENUM h.t.(p. 79)
21. Not as above	22
22. *Arnica cordifolia* well represented or a dominant forb of normally depauperate undergrowths	ABIES LASIOCARPA/ARNICA CORDIFOLIA h.t. (p. 79)
22. Not as above; *Pinus albicaulis* usually well represented and *Abies lasiocarpa* often stunted	PINUS ALBICAULIS - ABIES LASIOCARPA h.t (p. 80)

*h.t.s and phases incidental to central Idaho and omitted from charts and tables

Users of the classification should remember that not all series and habitat types occur in one area. In fact, a major floristic division occurs between the western and eastern portions of central Idaho. Figures 4 and 5 depict the general zonational sequence in these two areas at the series level.

Pinus flexilis Series

Distribution.—*Pinus flexilis* is primarily restricted to the continental climate of the Challis and Open Northern Rockies sections (fig. 2). Small populations were found on the Lost River, Lemhi, and Beaverhead Ranges. Other small populations were seen near the towns of Mackay, Ketchum, Challis, and Clayton. Isolated occurrences were confirmed from southwest of Cobalt (Ron Hamilton, Salmon National Forest, personal communication) and the Little Salmon River Canyon (Frederic D. Johnson, Univ. of Idaho, personal communication). *Pinus flexilis* also occupies certain volcanic substrates near Craters of the Moon National Monument (Eggler 1941). However, the extensive populations mapped by Little (1971) elsewhere in central Idaho could not be confirmed.

The *Pinus flexilis* series frequently occurs below the lower limits of *Pseudotsuga* forest. It also appears on exposed rocky slopes within the *Pseudotsuga* zone. In both cases, these are the driest forested sites in the area.

Vegetation.—*Pinus flexilis* is the only tree present or, more often, is a climax codominant with *Pseudotsuga*. In the latter case, neither species appears capable of outcompeting the other. Undergrowths usually resemble the adjacent nonforest communities dominated by *Hesperochloa kingii, Festuca idahoensis,* or *Cercocarpus ledifolius*.

Soil.—The *Pinus flexilis* series shows its best development on calcareous soils of the Lemhi and Lost River Ranges. Where sampled, these soils are gravelly silt loams to very gravelly loams. Exposed soil or surface rock seldom exceed 30 percent coverage. Litter depths on the better sites averaged only 3 cm.

Productivity/Management.—*Pinus flexilis* sites have little potential for producing timber. Regeneration of both *Pinus* and *Pseudotsuga* is sporadic and growth rates and stockability are low. In most cases, resources for grazing and wildlife outweigh other values.

Other studies.—Habitats dominated by *P. flexilis* have been described in Montana (Pfister and others 1977), in Wyoming (Reed 1969; Despain 1973; Wirsing 1973; Cooper 1975), and in Utah (Ellison 1954; Ream 1964; Henderson and others 1976, unpubl. ref.).

PINUS FLEXILIS/HESPEROCHLOA KINGII H.T. (*PIFL/HEKI*; LIMBER PINE/SPIKEFESCUE)

Distribution.—*PIFL/HEKI* is an incidental h.t. in the southern end of the Lemhi and Beaverhead Ranges. From here it extends eastward, appearing sporadically in extreme southern Montana and becoming more common in Wyoming. In central Idaho *PIFL/HEKI* normally occupies severe, windy, south-facing sites. Here, it borders nonforest communities at 7,800 to 8,800 feet (2 380 to 2 680 m) in areas that have *Abies* or *Picea* on north slopes.

Vegetation.—Widely spaced *Pinus flexilis* with various amounts of *Pseudotsuga* dominate a bunchgrass undergrowth. Stands generally resemble an open forest or savanna with *Hesperochloa kingii* and (usually) *Agropyron spicatum* as codominant grasses.

Productivity/Management.— Grazing by livestock is usually light. Slopes are usually steep and the livestock prefer adjacent flats and meadows. Although generally underutilized, forage production is low. Mule deer use is frequent but light.

Other studies.— This h.t. occurs in southeastern Wyoming (Wirsing 1973) and in western Wyoming (Steele and others 1979, unpubl. ref.). Pfister and others (1977) note that the portion of their *Pinus flexilis/Agropyron spicatum* h.t. in southern Montana is similar to *PIFL/HEKI*.

PINUS FLEXILIS/FESTUCA IDAHOENSIS H.T. (*PIFL/FEID*; LIMBER PINE/IDAHO FESCUE)

Distribution.—This minor h.t. occurs in the Open Northern Rockies section near lower limits of the forested zone at 6,600 to 8,300 feet (2 010 to 2 530 m) in elevation. It occupies various cool, dry aspects that usually border sagebrush-grass communities containing *Festuca idahoensis*. Adjacent moister sites are usually *Pseudotsuga* forest.

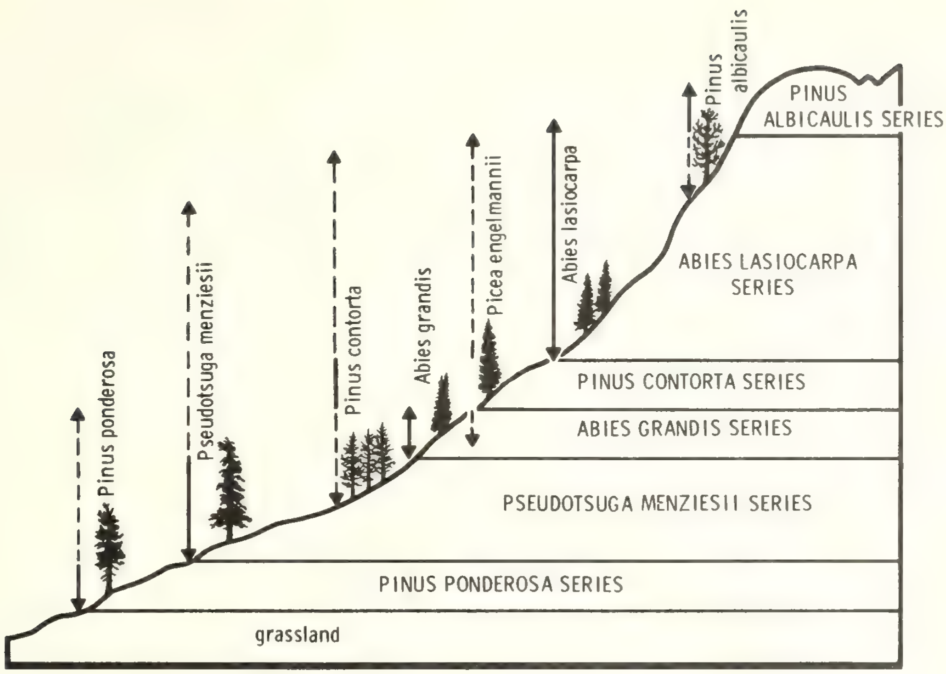


Figure 4. — General distribution of forest trees in west-central Idaho. Arrows show the relative elevational range of each species; solid portion of the arrow indicates where a species is the potential climax, dashed portion shows where it is seral.

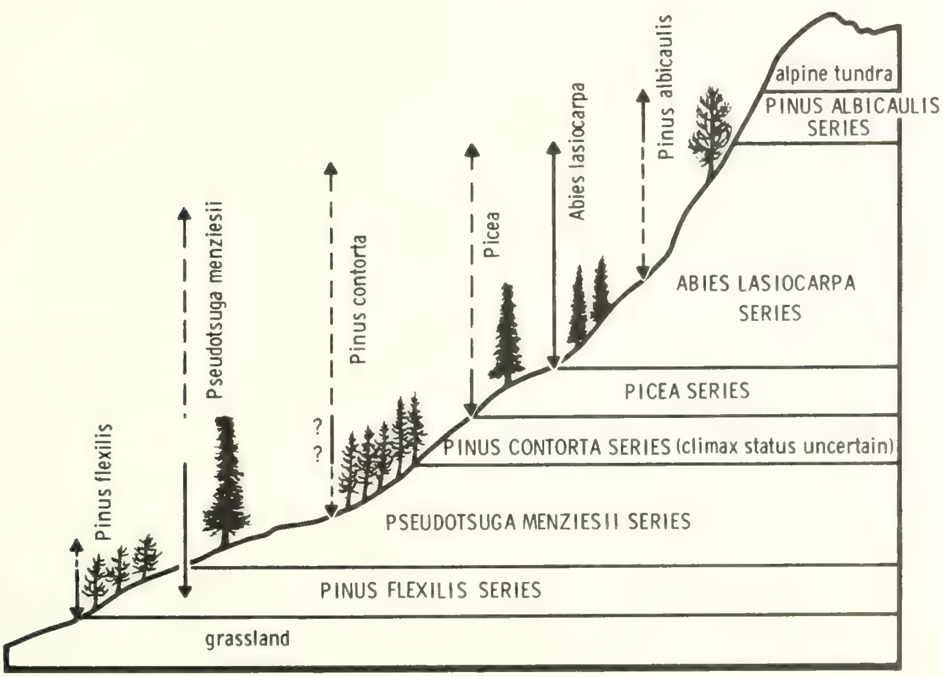


Figure 5. — General distribution of forest trees in east-central Idaho. Arrows show the relative elevational range of each species; solid portion of the arrow indicates where a species is the potential climax, dashed portion shows where it is seral.

Vegetation.—Bunchgrasses and numerous forbs dominate beneath open stands of *Pinus flexilis* and *Pseudotsuga. Festuca idahoensis* may codominate with either *Agropyron spicatum* or *Hesperochloa kingii.* Occasionally *Artemisia tridentata* ssp. *vaseyana* is conspicuous, but other shrubs occur only in minor amounts.

Fire.—Fire frequency seems quite low in this h.t. Fires that do occur here apparently have low intensity and cause little damage to larger trees. Most of the grasses and forbs quickly regenerate from underground organs.

Productivity/Management.—Cattle make moderate use of this h.t., apparently with little damage to the site. Elk and bighorn sheep find important winter forage here and mule deer use these sites for cover.

Other studies.—In Montana, Pfister and others (1977) recognized two phases of this h.t. In central Idaho, only the *Festuca idahoensis* phase was found and it appears comparable to that described in Montana. Small amounts of *PIFL/FEID* also occur in western Wyoming (Steele and others 1979, unpubl. ref.).

PINUS FLEXILIS/CERCOCARPUS LEDIFOLIUS H.T. *(PIFL/CELE;* LIMBER PINE/CURL-LEAF MOUNTAIN-MAHOGANY)

Distribution.—This incidental h.t. ranges from eastern central Idaho to the Wyoming border and southward to the Wasatch Mountains of northern Utah. It ranges from 7,000 to 8,400 feet (2 130 to 2 560 m) where it usually occupies southerly aspects and merges with *Cercocarpus* dominated communities at lower timberline.

Vegetation.—Open stands of *Pinus flexilis,* often with *Pseudotsuga,* dominate a layer of *Cercocarpus. Juniperus scopulorum* may be present in various amounts and *Berberis repens* and *Symphoricarpos oreophilus* are also common. The most common grasses are *Hesperochloa kingii* and *Agropyron spicatum.*

Productivity/Management.—Existing trees have their greatest value as a source of food and shelter for wildlife. The *Cercocarpus* provides big game with important browse and winter protection but may limit production of forbs and grasses.

Other studies.—*PIFL/CELE* also occurs in northern Utah and adjacent Idaho (Henderson and others 1976, unpubl. ref.) and in eastern Idaho (Steele and others 1979, unpubl. ref.).

PINUS FLEXILIS/JUNIPERUS COMMUNIS H.T. *(PIFL/JUCO;* LIMBER PINE/COMMON JUNIPER)

Distribution.—This incidental h.t. occurs sporadically from the Lost River and Lemhi Mountains to south central Montana and western Wyoming. It was found from 8,000 to 9,200 feet (2 440 to 2 800 m) on severe southerly to westerly aspects where *Pseudotsuga* forest occurs on more favorable adjacent sites.

Vegetation.—Open stands of *Pinus flexilis* and *Pseudotsuga* codominate scattered patches of *Juniperus communis* (fig. 6). Forbs are normally sparse, with *Astragalus miser* being the most common. Many calcareous surface rocks often cover much of the site.

Productivity/Management.—Livestock use is very light, due to the difficult accessibility and poor forage. Mule deer and possibly bighorn sheep apparently make use of these sites.

Other studies.—Pfister and others (1977) describe this h.t. in Montana where it is more common than in central Idaho. Steele and others (1979, unpubl. ref.) describe it in western Wyoming.

Pinus ponderosa Series

Distribution.—In northwestern portions of central Idaho, *Pinus ponderosa* forms climax stands that border grasslands and also is a common seral tree on many other forest sites. To the south and east, the country becomes drier and the minimum moisture required for pine establishment occurs at increasingly higher elevations. Here, pine gradually becomes scarce because of cold temperatures. Eastern limits of the *Pinus ponderosa* series lie near the eastern boundaries of the Southern Batholith and Salmon Uplands sections with minor extensions into drainages of the North Fork of the Salmon River.

Vegetation.—Usually *Pinus ponderosa* is the only tree in this series, but occasionally *Populus tremuloides* is also found. Drier sites have undergrowth vegetation typical of adjacent nonforest communities. Moister sites have undergrowth similar to part of the *Pseudotsuga menziesii* series.

Typical dominants of adjacent nonforest include *Agropyron spicatum, Artemisia tridentata, Purshia tridentata,* and *Symphoricarpos oreophilus.* Dominants common also in the *Pseudotsuga* series are mainly *Symphoricarpos albus* and *Physocarpus malvaceus.*

Soil.—Most soils in the *Pinus ponderosa* series are derived from granitics, basalt, or andesite. Habitat types in this series show little overall relationship to parent material (appendix D) although local distribution patterns may be evident. Soils derived from granitics and andesite are mostly sandy loams to loamy sands, some of which are also gravelly. Those from basalt range from silty clay-loam to loam. Soil pH ranges from 5.0 to 6.8, with most samples between 5.5 and 6.5. No correlation between pH and h.t. was evident.

Fire.—Fire has had minor effects on vegetation within this series. Although most sites contain some charcoal, fire scars suggest lightning strikes on a few trees, coupled with slowly creeping fires that kill only the smaller trees. Grasses, forbs, and most shrubs

Figure 6. — Pinus flexilis/Juniperus communis *h.t. on a westerly exposure h.t. in the Lemhi Mountains northeast of Patterson, Idaho (9,200 feet [2 800 m] elevation).* Pinus flexilis *and scattered* Pseudotsuga menziesii *dominate the stand.* Juniperus communis *forms scattered patches in a very depauperate undergrowth.*

regenerate quickly from underground organs. Most fires in this series apparently occurred more than 60 years ago. The recent reduction in fire may be credited to control efforts, but continued grazing has also maintained low levels of light fuels on these sites.

Productivity/Management.—The *Pinus ponderosa* series reflects some of the least productive timberland in the area. Because no other conifer is successful here, the existing trees must be managed prudently to maintain a tree cover. Tree regeneration is sometimes sporadic and may coincide with periodic burning or years of higher moisture. Forage value for grazing often outweighs other values of these sites. Most undergrowth consists of dry-site shrubs and grasses which grow well beneath open canopies of pine. These plants can produce considerable forage most years, but recovery from overuse often requires several years or even decades.

Trees in most stands of this series appeared free of disease. Dwarf mistletoe *(Arceuthobium* spp.) was observed in 15 percent of the stands. It was about equally distributed in all h.t.'s except where *Stipa* dominated the undergrowth and probably it would be found there too if more stands were sampled. The sporadic but widespread occurrence of mistletoe in central Idaho contrasts markedly with findings of other studies. In northern Idaho and eastern Washington, R. and J. Daubenmire (1968) noted widespread infection that was restricted to sites where dry-site grasses or *Purshia* dominated the undergrowth. In Montana, it was not found at all (Pfister and others 1977).

Very little insect damage to pine was observed in this series. However, in 1972, populations of pine butterfly *(Neophasia menapia)* were exceptionally large along the lower South Fork of the Salmon River where several *Pinus ponderosa* h.t.'s are common.

PINUS PONDEROSA/STIPA OCCIDENTALIS H.T. (*PIPO/STOC;* PONDEROSA PINE/WESTERN NEEDLEGRASS)

Distribution.—Minor amounts of *PIPO/STOC* occur along the South Fork of the Payette and South and Middle Forks of the Boise River. This h.t. ranged from 3,500 to 4,800 feet (1 070 to 1 460 m) and was found on very gentle river terraces in areas where the *PIPO/AGSP* h.t. was common on steeper slopes.

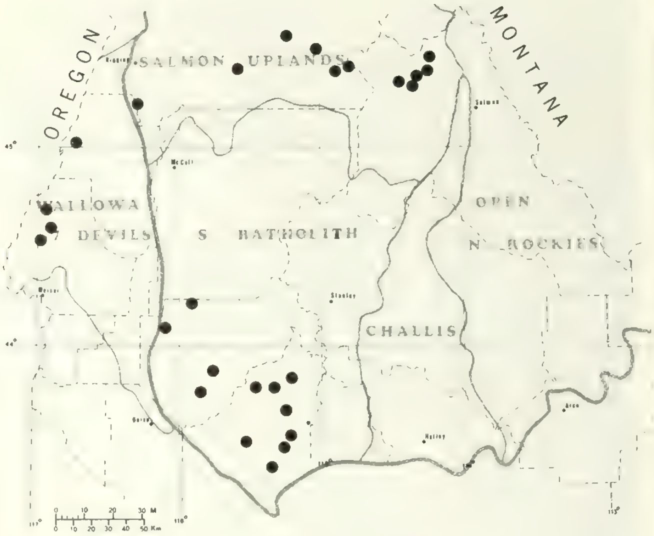
Vegetation.—Widely spaced *Pinus ponderosa* dominate a sparse layer of *Stipa occidentalis.* On some very similar sites, *Stipa thurberiana* was the undergrowth dominant. Small amounts (poorly represented) of *Purshia tridentata* are usually present but shrubs in general are very inconspicuous.

Soil.—The soils appear to be old alluvial deposits and are mainly sandy loams (appendix D). Soil pH ranged from 5.3 to 6.2 and averaged 5.7. Exposed surface rock varies from 0.5 to 15 percent and bare soil ranges from 0 to 30 percent. Litter depths are less than 3.5 cm.

Productivity/Management.—Timber productivity is apparently very low to low and of poor quality. The trees regenerate sporadically and form open stands with limited stocking. Forage production is low, but the gentle terrain attracts livestock. Use by wildlife is generally light.

Other studies.—R. and J. Daubenmire (1968) describe a *Pinus ponderosa/Stipa comata* h.t. in eastern Washington that appears very similar to *PIPO/STOC.* In fact, two of their stands were dominated by *Stipa thurberiana* in the undergrowth and three *Stipa* spp. now treated as *S. occidentalis* by Hitchcock and Cronquist (1973) also appeared in their stands.

PINUS PONDEROSA/AGROPYRON SPICATUM H.T. (*PIPO/AGSP;* PONDEROSA PINE/BLUEBUNCH WHEATGRASS)



Distribution.—The *PIPO/AGSP* h.t. occurs mostly near lower timberline in the Southern Batholith, Salmon Uplands, and Wallowa-Seven Devils sections. This h.t. ranges from 3,300 to 5,100 feet (1 010 to 1 550 m) and usually occupies steep slopes having southerly aspects.

In most cases the *PIPO/AGSP* h.t. reflects the hot, dry extreme of the forested zone. It normally occurs between steppe communities and more moist *Pinus ponderosa* h.t.'s, but in some areas it simply occupies the driest sites within the forest mosaic.

Vegetation.—The bunchgrass ecotype of *Agropyron spicatum* dominates the undergrowth of undisturbed stands. Near the Sawtooth Mountains *Melica bulbosa* also becomes a dominant species. With grazing, annuals and unpalatable forbs gradually replace *A. spicatum* but *Artemisia tridentata* seldom becomes dominant.

In the Southern Batholith section, the *PIPO/AGSP* h.t. occupies granitic soils that have high erosion potential. Here, this h.t. supports a depauperate forb component. In the Wallowa-Seven Devils section it occurs mostly on basalt—and some andesite—derived soils that are much less erosive and support many forbs. Here, *Lomatium dissectum* var. *multifidum* often codominates with *Agropyron spicatum* (fig. 7).

Soil.—Soils range from loam to clay loam on basalt and andesite, and from sandy loam to loamy sand on granitics (appendix D). Soil pH varies from 5.2 to 6.8 and averages 6.0. The soils on granitics are slightly more acidic, but this is not always the case. Areas of exposed rock or soil are often high, up to 75 percent. Litter is shallow, usually less than 2.5 cm.

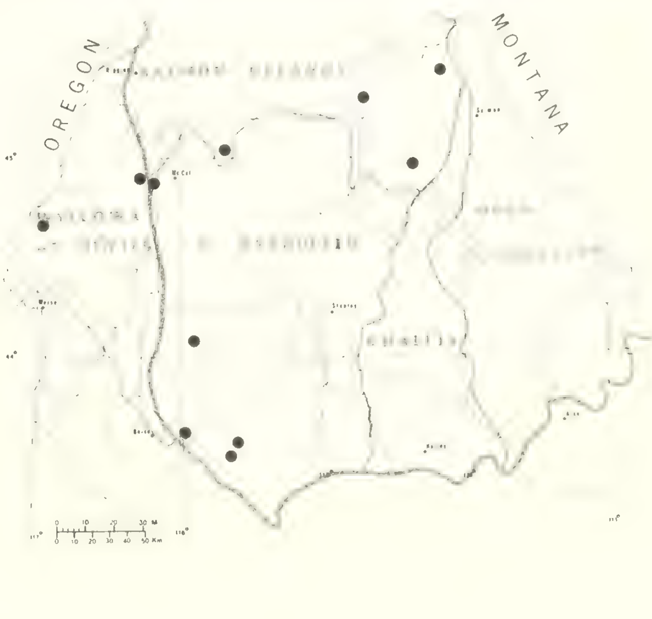
Figure 7. — Pinus ponderosa/Agropyron spicatum *h.t. on a steep southerly exposure in the Hitt Mountains west of Cambridge, Idaho (4,200 feet [1 280 m] elevation). Scattered* Pinus ponderosa *form an open stand which dominates a layer of* Agropyron spicatum *and* Lomatium dissectum.

Productivity/Management.—Timber productivity is low to very low because of low site index (appendix E-1) and apparent stockability limitations (appendix E-2). Natural regeneration requires a long time to produce adequate stocking. Artificial regeneration would be expensive because the probability of survival is very low.

These sites can produce good forage for livestock, but unregulated grazing can easily reduce forage production and create considerable erosion. On ranges used by both livestock and big game, forage production may need to be allocated, depending on objectives. Big game forage production is low; but the big game winter demand may be relatively high. In some areas, the dried grasses provide important winter forage for elk and bighorn sheep. The large, spreading trees may provide winter cover for mule deer and important roosts for wild turkey.

Other studies.—The *PIPO/AGSP* h.t. has been recognized in several adjacent areas. It was described in northern Idaho and eastern Washington by R. and J. Daubenmire (1968) and in Montana by Pfister and others (1977). In central Idaho, this h.t. includes minor amounts of *Festuca idahoensis,* as opposed to the Daubenmires' description, but it does not contain the Great Plains species included in Pfister's and others (1977) description. In the Blue Mountains of Oregon, Hall's (1973) "ponderosa pine-wheatgrass without shrubs" appears comparable to our *PIPO/AGSP* h.t.

PINUS PONDEROSA/FESTUCA IDAHOENSIS H.T. (*PIPO/FEID;* PONDEROSA PINE/IDAHO FESCUE)



Distribution.—The *PIPO/FEID* h.t. occurs in minor amounts wherever *Pinus ponderosa* is climax. It is probably most common from 3,500 to 5,800 feet (1 070 to 1 770 m) in canyons of the Salmon Uplands section near lower timberline. It often occupies north and east aspects in areas where the *PIPO/AGSP* h.t. is found on south and west exposures. Thus *PIPO/FEID* appears slightly more moist than *PIPO/AGSP* and the cooler aspects often compensate for the dry climatic conditions. The usual relative position for the *PIPO/FEID* h.t. is between *PIPO/AGSP* or nonforest *Festuca idahoensis* communities and the *PIPO/SYAL* h.t.

Vegetation.—*Festuca idahoensis* and *Agropyron spicatum* are the dominant grasses on sites in good condition. Forbs are more common here than in the *PIPO/AGSP* h.t. and usually include *Balsamorhiza sagittata, Achillaea millefolium,* and *Eriogonum heracleoides. Artemisia tridentata* ssp. *vaseyana* is also more common here than in *PIPO/AGSP.*

Soil.—Soils are mainly of granitic or basaltic origin (appendix D). Textures range from loam to clay loam on basalts and from loam to gravelly loamy sand on granitics. Soil pH varies from 5.5 to 6.7 and averages 6.1. In contrast to *PIPO/AGSP,* surface rock varies from 0 to only 20 percent, and bare soil ranges from 0.5 to 20 percent. Litter depths vary from 0.3 to 7.5 cm.

Productivity/Management.—Timber productivity is low (appendix E-2). Management considerations are similar to *PIPO/AGSP;* however, forage production should be greater due to a more moderate environment and greater number of plant species (appendix C). Wildlife and livestock considerations are similar to those of *PIPO/AGSP.*

Other studies.—Our *PIPO/FEID* h.t. is similar to the *FEID* phase of this h.t. in Montana (Pfister and others 1977). In eastern Washington, R. and J. Daubenmire (1968) described a *PIPO/FEID* h.t. that has less *Agropyron spicatum.* A "ponderosa pine-fescue" community also exists in the northern Blue Mountains (Hall 1973). One of our stands near the Little Salmon River resembles Hall's (1973) "ponderosa pine - fescue and mahogany" community type, but our small acreage precluded recognition as a h.t. or phase.

PINUS PONDEROSA/PURSHIA TRIDENTATA H.T. (*PIPO/PUTR;* PONDEROSA PINE/BITTERBRUSH)

•*Agropyron spicatum* phase (*AGSP;* bluebunch wheatgrass)

★ *Festuca idahoensis* phase (*FEID;* Idaho fescue)

Distribution.—The *PIPO/PUTR* h.t. occurs mostly on dry southerly slopes and benches in the Southern Batholith section. It also appears in the Wallowa-Seven Devils and Salmon Uplands sections. Most sites ranged from 3,000 to 5,000 feet (910 to 1 520 m), occurring either near lower timberline or as dry sites within lower elevations of the forest mosaic. A few sites were as high as 6,500 feet (1 980 m) but maintained the same relative position.

Vegetation.—Open stands of *Pinus ponderosa* dominate a layer of *Purshia* (fig. 8). On sites in good condition, *Agropyron spicatum* usually dominates between the shrubs. Other grasses and forbs are usually present and include *Achillaea millefolium* and *Balsamorhiza sagittata.*

Agropyron spicatum (AGSP) phase.—This is the most common phase in much of central Idaho. Its description fits that given above. At its dry extreme, this phase usually borders nonforest communities or the *PIPO/AGSP* h.t. At the moist extreme, this phase may merge with a *PIPO/SYAL* or *PSME/SPBE* h.t.

Festuca idahoensis (FEID) phase.—In some areas, especially the Salmon Uplands section, *Festuca idahoensis* is well represented beneath the layer of *Purshia* and may even codominate with *Agropyron.* This phase usually borders a nonforest community or the *PIPO/FEID* h.t. at the dry extreme and the *PIPO/SYAL* h.t. at the moist extreme.

Soil.—Soil parent materials are mainly andesite, rhyolite, and granitics (appendix D). A few sites occur on basalts. Soil textures vary from gravelly loamy sand

Figure 8. — Pinus ponderosa/Purshia tridentata *h.t.,* Festuca idahoensis *phase on an alluvial terrace near Indian Creek, Middle Fork Salmon River (4,600 feet [1 400 m] elevation).* Pinus ponderosa *forms an open stand over a layer of* Purshia tridentata. Festuca idahoensis *is the predominant grass between the shrubs.*

to clay loam but are mostly sandy loam to loamy sand. Soil pH ranges from 5.0 to 6.4, with both extremes from granitic soils. Coverages of both surface rock and bare soil range from 0 to 30 percent. The large areas of bare soil have resulted either from livestock, or earth movement on steep slopes. Average litter depth seldom exceeds 4 cm.

Productivity/Management.—Timber productivity ranges from low to very low (appendix E-2). Some forage is available for livestock but grazing abuse can easily deplete production potential. In some areas, elk and mule deer use this h.t. heavily for winter forage and cover and, in spring, black bear feed heavily on the perennial grasses and forbs. The large spreading trees may also provide roosts for wild turkey.

Other studies.—*PIPO/PUTR* also occurs in eastern Washington (R. and J. Daubenmire 1968) and in Montana (Pfister and others 1977). In the Blue Mountains, Hall (1973) lists three "pine/bitterbrush" community types each having a different graminoid dominating the shrub interspaces.

PINUS PONDEROSA/SYMPHORICARPOS OREOPHILUS H.T. (*PIPO/SYOR;* PONDEROSA PINE/MOUNTAIN SNOWBERRY)

Distribution.—This minor h.t. was seen only in southern portions of the Wallowa-Seven Devils and Southern Batholith sections. It typically occurs on southerly ridges and upper slopes at around 5,000 feet (1 520 m) and is best described as an overlap between *Pinus ponderosa* and the mountain shrub communities of *Symphoricarpos oreophilus*. Adjacent sites that are less severe are usually a *Pseudotsuga* h.t.

Vegetation.—Very open stands of *Pinus ponderosa* dominate a shrubby layer that contains various amounts of *Symphoricarpos oreophilus, Purshia tridentata, Amelanchier alnifolia, Artemisia tridentata,* and *Prunus virginiana. Agropyron spicatum, Balsamorhiza sagittata,* and *Eriogonum* spp. are common in the herbaceus layer.

Soil.—These dry sites often have shallow rocky soils but are cooler than most *Pinus ponderosa* h.t.'s. Basalts and granitics are the common parent materials. In the three samples taken (appendix D), soil texture varied from loam to clay loam and pH ranged from 6.1 to 6.2. Litter depth is usually less than 3.5 cm. The sites have only small amounts of exposed rock (2 percent or less) and less than 10 percent bare soil.

Productivity/Management.—Trees regenerate sporadically and the stocking is very limited. Timber productivity of existing trees apparently is low. Forage production for livestock is limited by the shrub layer while the upper slope position of this h.t. seldom attracts much use. In some areas, wintering elk feed heavily on these sites and mule deer find important food and cover here. In spring, this h.t. may be important for mule deer fawning and rearing and for black bear that feed on perennial grasses and forbs. Blue grouse will also nest and raise their young here. Fall berry crops may be important to blue grouse and black bear.

Other studies.—The *PIPO/SYOR* h.t. has not been described elsewhere.

PINUS PONDEROSA/SYMPHORICARPOS ALBUS H.T. (*PIPO/SYAL*; PONDEROSA PINE/ COMMON SNOWBERRY)

Distribution.—The *PIPO/SYAL* h.t. is common throughout the Wallowa-Seven Devils section. It is also common in western canyons of the Salmon Uplands section, but becomes increasingly scarce toward the eastern edge. It occurs in western portions of the Southern Batholith section, but eastward in the Boise River drainage it becomes scarce and is restricted to alluvial fans, land slumps, and stream terraces. Most sites are below 5,000 feet (1 520 m) and border the lower limits of *Pseudotsuga* forest.

Vegetation.—Fairly open stands of *Pinus ponderosa* dominate a layer of low shrubs (fig. 9). *Symphoricarpos albus* is well represented and usually dominant. *Spiraea betulifolia* and *Rosa* spp. may be codominant. A few stands contain high coverages of *Calamagrostis rubescens* or *Carex geyeri,* but most of these sites occur at the upper limits of *PIPO/SYAL* within a mosaic of *Pseudotsuga* forest.

Soil.—These sites normally have well-drained, sandy loam to clay loam soils (appendix D). Most parent materials are basalt or granitic. Soil pH varies between 5.6 and 6.4 and averages 5.9. Unless disturbed, these sites have only trace amounts of bare soil or rock and litter depths often reach 4 to 6 cm.

Productivity/Management.—This h.t. produces more timber than most other sites where *Pinus ponderosa* is climax (appendix E-2) and trees seem to regenerate more readily. Amounts of livestock forage will vary with grass species and coverage (appendix C). Big game forage is limited by the few palatable shrub species present, but deer and elk make light to moderate use of these sites.

Other studies.—North of our area, R. and J. Daubenmire (1968) described a similar h.t. In Montana, Pfister

Figure 9. — Pinus ponderosa/Symphoricarpos albus *h.t. on a gentle easterly exposure near Price Valley Guard Station west of New Meadows, Idaho (4,550 feet [1 370 m] elevation).* Pinus ponderosa *dominates a layer of* Symphoricarpos albus *and* Spiraea betulifolia. *This stand contained high coverages of* Calamagrostis rubescens *and bordered a* PSME/SYAL *h.t.*

and others (1977) described a more extensive and variable type with two phases. Their *Symphoricarpos albus* phase is most comparable to our h.t.

PINUS PONDEROSA/PHYSOCARPUS MALVACEUS H.T. *(PIPO/PHMA;* PONDEROSA PINE/NINEBARK)

Distribution.—Small amounts of this incidental h.t. were found in the South Fork Payette and Little Salmon River drainages. It becomes more common north of our study area.

Vegetation.—*Pinus ponderosa* dominates an undergrowth similar to that of the *PSME/PHMA* h.t. *Physocarpus malvaceus* is the dominant shrub, with a layer of *Symphoricarpos albus* beneath.

Soil.—Soils vary from silty loam to loamy sand and are derived from basalt or granitic material. Of the three samples taken, soil pH ranged from 5.6 to 6.3. Only 0 to 2 percent bare soil was found; exposed rock was absent. Litter depths ranged from 3 to 8 cm.

Productivity/Management.—Timber production should be similar to that of the *PIPO/SYAL* h.t. Utility for livestock and wildlife should be similar to that of the *PSME/PHMA* h.t.

Other studies.—This h.t. was described by R. and J. Daubenmire (1968) in northern Idaho and eastern Washington.

Pseudotsuga menziesii Series

Pseudotsuga menziesii occupies the broadest range of environmental conditions of any conifer in central Idaho both as a seral and as a climax species. It ranges from areas that receive the strongest maritime influence to those enduring the strongest continental climate and in certain areas grows from lower timberline to some topoedaphic upper timberlines. The broad ecologic amplitude of *Pseudotsuga* is evidence of considerable genetic diversity. North of our area, Rehfeldt (1974) showed that substantial genetic variation exists in *Pseudotsuga,* not only between populations in different areas but also between certain h.t.'s. In central Idaho, nursery-grown seedlings of *Pseudotsuga* also indicate substantial genetic differences between populations (Frank Morby, Lucky Peak Nursery, personal communication). In the nursery, seed from different areas in central Idaho produce not only seedling populations with notably different heights, but also considerable height diversity within populations. This suggests a strong potential for improving nursery stock through genetic selection.

Distribution.—The genetic diversity of *Pseudotsuga* no doubt contributes to the extensive nature of the *Pseudotsuga menziesii* series. In the Challis and Open Northern Rockies sections it often borders steppe vegetation at lower timberline or it may border the *Pinus flexilis* series. Near its dry limits in the Wallowa-Seven Devils, Salmon Uplands, and Southern Batholith sections, the series usually merges with the *Pinus ponderosa* series. At higher elevations throughout central Idaho it abuts the *Abies lasiocarpa* series except in the western portion where it usually meets the *Abies grandis* series.

Vegetation.—*Pinus ponderosa* is a vigorous seral conifer in major portions of the *Pseudotsuga* series. *Pinus contorta* will form dominant stands in a few h.t.'s but *Larix occidentalis* rarely occurs in this series. Where the *Pseudotsuga* series surpasses the elevational or geographical limits of *Pinus ponderosa, Pseudotsuga* is often the seral dominant as well as the climax dominant. Undergrowths vary from dense, shrubby layers to scattered, dry-site grasses. Several of the drier h.t.'s have an open-forest to savannah-like appearance.

Soil.—Soil parent materials vary widely in the *Pseudotsuga* series and range from granitic and volcanic materials to limestone (appendix D). In general, *Pseudotsuga* h.t.'s show little affinity for a particular soil condition although such relationships often occur locally. Exceptions to the above are noted within the appropriate h.t. description.

Fire.—Fire has strongly influenced stand development in portions of this series. *Pseudotsuga* h.t.'s in the Challis and Open Northern Rockies sections have experienced only slight alteration by fire, whereas those in northern and western portions of central Idaho reflect relatively more fire influence. Here fire-induced *Pinus ponderosa* dominates or, more often, codominates with older *Pseudotsuga* whose thick bark provides protection from fire.

In some h.t.'s of this series, burning or logging may result in a layer of *Ceanothus velutinus* or unusually high coverages of *Calamagrostis rubescens*. Seeds of the *Ceanothus* can remain dormant in forest stands for 200-300 years and germinate abundantly after fire (Gratkowski 1962). The resulting layer of *Ceanothus* may suppress conifer seedlings and dominate the undergrowth for several decades. Being rhizomatous, the *Calamagrostis* can increase rapidly following fire or logging and develop a dense sod that impedes establishment of other species including trees.

Productivity/Management.—Productivity and response to management vary widely in this series as noted in the h.t. descriptions. Over much of the series *Calamagrostis rubescens* proliferates after fire or logging and develops extensive sod. This condition requires careful site preparation for successful regeneration of conifers. On certain soils, Stewart and Beebe (1974) found chemical treatment more effective than mechanical removal of *C. rubescens* for survival of *Pinus ponderosa* seedlings; however, thorough scarification suffices on most sites in central Idaho.

Dwarf mistletoe *(Arceuthobium* spp.) occurs in many stands and varies considerably in severity of infection. Locally, infection may appear correlated with h.t., but no such relationship is evident throughout the distribution of any *Pseudotsuga* h.t. Perhaps this is because infection was assessed at one point in time and the potential for infection is not yet evident in all stands of a given h.t. Needlecast *(Rhabdocline pseudotsugae)* was notably severe in a few areas but, like mistletoe, shows little overall relationship with h.t.'s when based on a single sample of the area. Insect damage and sporophores of pathogenic fungi were also observed in minor amounts. However, these occurrences vary seasonally and provide little meaning when sampled in different stands throughout the field season.

PSEUDOTSUGA MENZIESII/AGROPYRON SPICATUM H.T. *(PSME/AGSP;* DOUGLAS-FIR/BLUEBUNCH WHEATGRASS)

Distribution.—*PSME/AGSP* occurs throughout much of central Idaho but is best developed in southern portions of the Southern Batholith section. It occupies steep southerly to westerly aspects from 3,800 to 7,500 feet (1 160 to 2 290 m) and in many areas forms the lower timberline. Elsewhere it represents the driest forested sites in the area. At its dry extreme, *PSME/AGSP* normally borders nonforest communities that have *Agropyron spicatum* as a major component. At the cool moist extremes, it most often borders a *PSME/CAGE* or *PSME/SPBE* h.t.

Vegetation.—Widely spaced *Pseudotsuga,* often with *Pinus ponderosa,* codominate an undergrowth of dry-site grasses and forbs creating an open-forest to savannah-like appearance. Normally, on sites in good condition, *Agropyron spicatum* dominates the undergrowth, but in the Sawtooth Mountains *Melica*

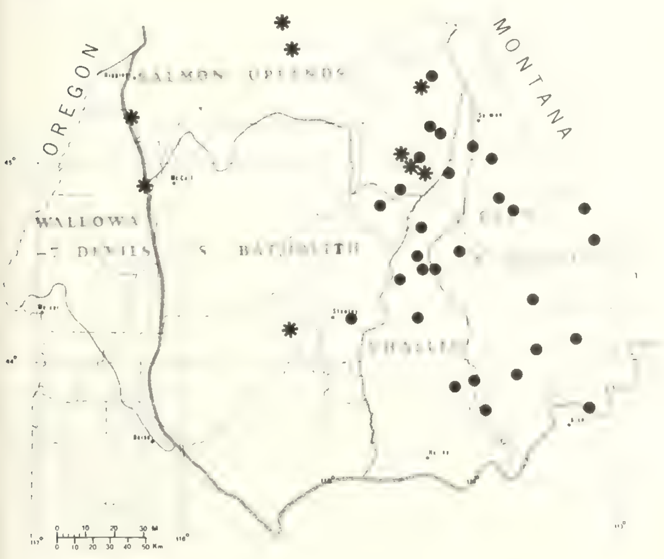
bulbosa occasionally codominates or even dominates this layer. With grazing, annuals and unpalatable forbs gradually replace the *Agropyron* and *Melica*. On some sites, especially those beyond the limits of *Pinus ponderosa, Artemisia tridentata* ssp. *vaseyana* creates a conspicuous layer in the openings.

Soils.—*PSME/AGSP* is found on soils derived from a variety of parent rock, ranging from basalt to quartzite (appendix D). Because much of central Idaho is occupied by the Idaho Batholith, most soils are of granitic origin. Soil pH ranges from 5.4 to 7.1, with a mean of 6.1. On steep slopes, as much as 60 percent of the surface is bare soil or rock. Litter depths seldom exceed 3 cm.

Productivity/Management.—*PSME/AGSP* has low to very low potential for producing timber (appendix E-2). Natural regeneration of trees is slow because of extreme droughty conditions and grass competition. These sites produce some forage for livestock but the steep slopes and loose soil may preclude domestic grazing. In some areas, elk, mule deer, and occasionally bighorn sheep find important forage or cover here, especially during the winter. These sites may also provide important spring forage for black bear and, where large *Pinus ponderosa* are present, important year-round habitat for wild turkey.

Other studies.—The *PSME/AGSP* h.t. is described in Montana (Pfister and others 1977) but has not been reported elsewhere.

PSEUDOTSUGA MENZIESII/FESTUCA IDAHOENSIS H.T. (*PSME/FEID*; DOUGLAS-FIR/IDAHO FESCUE)



•*Festuca idahoensis* phase (*FEID;* Idaho fescue)

**Pinus ponderosa* phase (*PIPO;* ponderosa pine)

Distribution.—*PSME/FEID* occurs mainly in the Challis and Open Northern Rockies sections, but it extends westward in the Salmon Uplands section. It occurs on mid- to lower slopes and benches at lower elevations of the forested zone. It appears most often on gentle to steep slopes having northerly to easterly aspects at elevations ranging from 3,000 to 8,000 feet (910 to 2 440 m).

PSME/FEID represents lower timberline throughout much of its area. At its dry extreme, it usually borders a nonforest community having *Festuca idahoensis* as a major component. At its moist extreme it merges most often with the *PSME/ARCO* and *PSME/CARU* h.t.'s.

Vegetation. — Normally, the trees form a broken canopy and create an open forest but tree density can vary from a nearly closed canopy to a savannah appearance (fig. 10). *Festuca idahoensis* is usually well represented and often accompanied by *Agropyron spicatum*. Numerous forbs are generally present but not always conspicuous.

Festuca idahoensis (FEID) phase. — This is the common phase in the Challis and Open Northern Rockies sections and it occurs at higher elevations (6,000 to 8,000 feet [1 830 to 2 440 m]) than the *PIPO* phase. Usually *Pseudotsuga* is the only tree present. *Antennaria microphylla* and *Arenaria congesta* are more common here than in the *PIPO* phase.

Pinus ponderosa (PIPO) phase. — This phase appears mainly in the Salmon Uplands section. It tends to occur on steeper slopes than the *FEID* phase and denotes a warmer, lower elevation (3,000 to 6,500 feet [910 to 1 980 m]) segment of the h.t. *Pinus ponderosa* is usually present as a codominant with *Pseudotsuga*. Small amounts of *Amelanchier, Prunus, Rosa,* and *Eriogonum* are more common here than in the *FEID* phase.

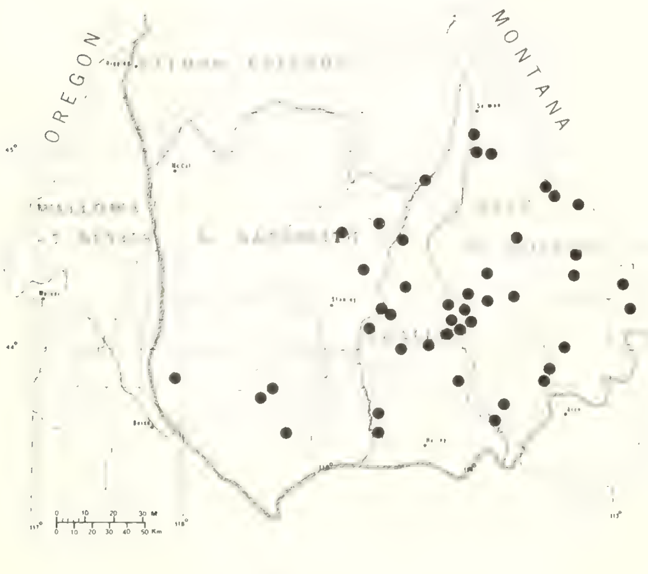
Soils. — The soils are derived from a variety of parent materials including quartzite, granitics, and various volcanics (appendix D). They range from silty loam to gravelly sandy loam but are mainly gravelly loams. Soil pH ranges from 5.4 to 6.7 and averages 6.1. Occasionally the amount of surface rock reaches 30 percent but usually it is less than 10 percent. Most sites have less than 5 percent of the area in bare soil. Average litter depth per site is usually less than 4 cm.

Productivity/Management. — Timber productivity is low to very low (appendix E-2) and tree regeneration is sporadic. Although some natural stands appear well stocked, natural regeneration is a slow process. The *FEID* phase tends to occur on more gentle, stable slopes, which makes it relatively compatible with livestock use. In some areas, values of livestock forage production may exceed those of timber. In other areas, elk, mule deer, and occasionally bighorn sheep and mountain goats find important forage or cover here, especially during the winter. This h.t. may also provide important spring forage for black bear and, in the *PIPO* phase, important year-round habitat for wild turkey.

Figure 10. — Pseudotsuga menziesii/Festuca idahoensis *h.t.,* Festuca idahoensis *phase on a dry bench in the Lemhi Mountains southwest of Lemhi, Idaho (6,900 feet [2 100 m] elevation).* Pseudotsuga menziesii *forms an open stand over a layer of* Festuca idahoensis. *Numerous forbs are present in small amounts.*

Other studies. — Our *FEID* phase fits the description of this h.t. in Montana (Pfister and others 1977). *PSME/FEID* is also reported in western Wyoming (Steele and others 1979, unpubl. ref.).

PSEUDOTSUGA MENZIESII/SYMPHORICARPOS OREOPHILUS H.T. (PSME/SYOR; DOUGLAS-FIR/MOUNTAIN SNOWBERRY)



Distribution. — *PSME/SYOR* is a minor h.t. across southern portions of the Challis, Open Northern Rockies, and Southern Batholith sections. It occurs mainly from 4,500 to 8,000 feet (1 370 to 2 440 m) near lower timberline on steep slopes having southerly to westerly aspects.

This h.t. can be considered an overlap of *Pseudotsuga* forest and mountain shrub communities. Adjacent nonforested areas are normally dominated by *Symphoricarpos oreophilus* with *Prunus* or *Artemisia* as a codominant shrub. Adjacent forested sites are usually the more moist *PSME/ARCO* h.t. in the Challis and Open Northern Rockies sections and the *PSME/CAGE* or *PSME/SPBE* h.t. in the Southern Batholith section.

Vegetation. — Usually *Pseudotsuga* is the only tree present and creates an open-forest to savannah-like appearance. Occasionally *Pinus flexilis* appears in small amounts and sometimes *Pinus ponderosa* may codominate with *Pseudotsuga. Pinus contorta* and *Pinus albicaulis* may appear as accidentals.

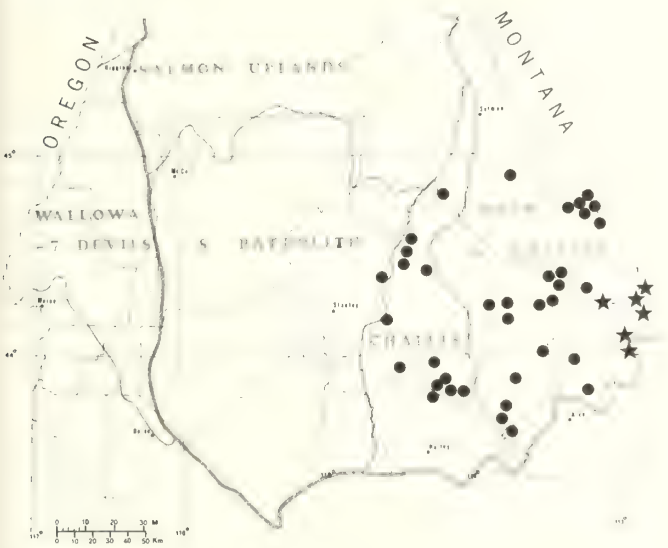
Symphoricarpos oreophilus is usually a dominant or codominant shrub. A few stands having only *Prunus virginiana* or *Ribes cereum* as the dominant shrub have been included in this h.t. *Agropyron spicatum* and a few dry-site forbs often dominate the shrub interspaces.

Soil. — Soils are derived from most major parent materials in the area (appendix D). Texturally they range from loam and gravelly silt loam to very gravelly loamy sand. Soil pH ranges from 8.0 to 6.0 and averages 6.8. Coverages of bare rock reach 70 percent on some sites and areas of bare soil attain 20 percent on other sites. Average litter depth on a site seldom exceeds 4.6 cm.

Productivity/Management. — Timber productivity is low to very low (appendix E-2) and trees regenerate very sporadically. Success at artificial regeneration is apt to be poor. The shrubs and grasses attract both wild and domestic herbivores and the tree canopies can shelter animals that use adjacent rangeland. These sites often provide important forage and cover for mule deer and blue grouse and, in some areas, are very important to wintering elk.

Other studies. — Reed (1969) describes a *PSME/SYOR* community in Wyoming that is broader than our h.t. Schlatterer (1972, unpubl. ref.) also describes a broader *PSME/SYOR* community type. Pfister and others (1977) report minor amounts of *PSME/SYOR* h.t. from southwestern Montana, and Steele and others (1979, unpubl. ref.) describe it in eastern Idaho and western Wyoming.

PSEUDOTSUGA MENZIESII/ARNICA CORDIFOLIA H.T. (*PSME/ARCO;* DOUGLAS-FIR/HEARTLEAF ARNICA)



•*Arnica cordifolia* phase (ARCO; heartleaf arnica)

★ *Astragalus miser* phase (*ASMI;* weedy milkvetch)

Distribution. — *PSME/ARCO* occurs in the Challis and Open Northern Rockies sections. It appears on various dry aspects at lower elevations of the forested zone where it ranges from 6,500 to 8,600 feet (1 980 to 2 620 m).

Vegetation. — *Pseudotsuga* is often the only conifer present but *Pinus contorta* and *P. flexilis* may occur here as seral species. When approaching climax, undergrowths are normally depauperate. Seral conditions may support shrubs such as *Artemisia tridentata* and *Cercocarpus ledifolius* which also grow on adjacent drier sites.

Astragalus miser (ASMI) phase. — This phase occurs in southern portions of the Lemhi and Beaverhead Mountains. Small amounts of *Pinus flexilis* appear more often here than in the *ARCO* phase and tree growth potential is somewhat less. *Astragalus miser* dominates a forb layer that is often even more depauperate than in the *ARCO* phase.

Arnica cordifolia (ARCO) phase. — This is the more common phase within the h.t. In old growth stands, *Arnica cordifolia* usually dominates a depauperate undergrowth (fig. 11). Sometimes *Astragalus miser* will codominate with the *Arnica* and may denote areas that are transitional to the *ASMI* phase.

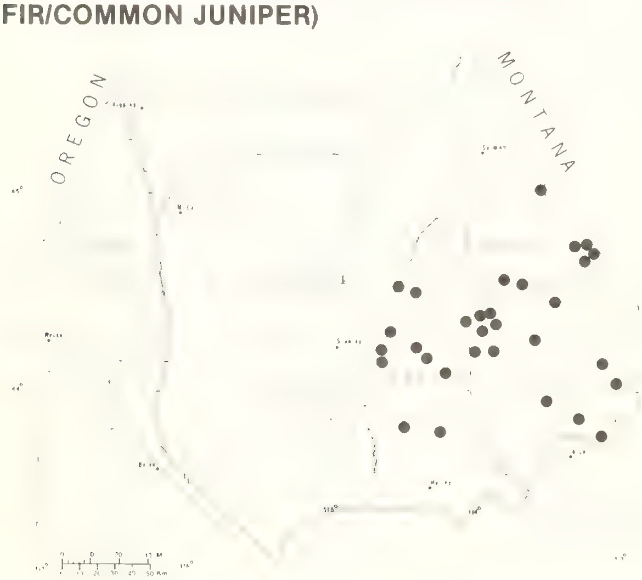
Soil. — Soil parent materials include limestone, quartzite, andesite, dacite, schist, and Challis basalt (appendix D). Soil textures range from sandy loam to silt loam and most are gravelly to very gravelly. The pH ranges from 5.3 to 8.2 and averages 6.8. Coverage of bare rock is usually less than 10 percent but can approach 70 percent. Litter often had a high coverage but its depth seldom averaged more than 7 cm on any one site.

Productivity/Mangement. — These sites support moderately heavy basal areas especially in the *ARCO* phase, but yield capability is within the low range (appendix E). Diameter growth increment in both phases appears to taper off rather quickly with age but we have no response data to evaluate effects of thinning on diameter growth. Natural reproduction is apparently sporadic but has not been studied in this h.t. Seral stands provide some forage for livestock but animals attracted to these sites may impede tree reproduction. Older stands offer little forage but provide shelter for animals that feed in nearby grasslands. In some areas these stands also provide important cover for deer and elk.

Other studies. — In Montana, Pfister and others (1977) describe *PSME/ARCO* but make no phase delineations. Both phases of *PSME/ARCO* also occur in western Wyoming (Steele and others 1979, unpubl. ref.).

Figure 11. — Pseudotsuga menziesii/Arnica cordifolia *h.t.,* Arnica cordifolia *phase near Doublesprings Pass, Lemhi Mountains northeast of Dickey, Idaho (7,860 feet [2 400 m] elevation). A pure stand of* Pseudotsuga menziesii *dominates a depauperate undergrowth in which* Arnica cordifolia *is the predominant forb.*

PSEUDOTSUGA MENZIESII/JUNIPERUS COMMUNIS H.T. (*PSME/JUCO*; DOUGLAS-FIR/COMMON JUNIPER)



Distribution. — This h.t. occurs mainly in the Challis and Open Northern Rockies sections of Idaho and in adjacent Montana. It normally appears from 7,500 to 8,400 feet (2 290 to 2 560 m) on exposed rocky sites at lower to mid-elevations of the forested zone.

Vegetation. — Usually *Pseudotsuga* is the predominant tree, with lesser amounts of *Pinus flexilis, P. contorta,* and sometimes *P. albicaulis. Juniperus communis* gradually forms large patches that are easily destroyed by fire. *Symphoricarpos oreophilus* is normally present and *Shepherdia canadensis* often occurs in younger stands. *Arnica cordifolia* usually dominates a depauperate forb layer.

Soil. — Soil parent materials are mainly quartzite, with occasional stands occurring on limestone or granitics (appendix D). Soils are usually gravelly or very gravelly loams or silt loams and contain a high proportion of angular cobbles and stones. Soil pH ranges from 6.1 to 8.1 and averages 7.1. Coverage of bare rock can reach 40 percent and areas of bare soil 10 percent. Average litter depth seldom exceeds 4 cm.

Productivity/Management. — Timber potential is low to very low (appendix E-2). When present, *Pinus contorta* may be in a marginal environment and not respond well to management. Regeneration of *Pseudotsuga* may be sporadic and timber harvests should be guided by the patterns and frequency of regeneration observed in the stand. Most of these sites have little potential for livestock, but may provide important cover for deer and elk.

Other studies. — *PSME/JUCO* h.t. also occurs in Montana (Pfister and others 1977) and small areas appear in western Wyoming (Steele and others 1979, unpubl. ref.).

PSEUDOTSUGA MENZIESII/CAREX GEYERI H.T. (*PSME/CAGE*; DOUGLAS-FIR/ELK SEDGE)

•*Carex geyeri* phase
(*CAGE;* elk sedge)

★ *Symphoricarpos oreophilus* phase
(*SYOR;* mountain snowberry)

* *Pinus ponderosa* phase
(*PIPO;* ponderosa pine)

Distribution. — *PSME/CAGE* occurs mainly in the Southern Batholith section but extends into most other sections of central Idaho. It occurs on dry aspects throughout much of the *Pseudotsuga* zone and ranges from 3,700 to 8,700 feet (1 130 to 2 650 m). It occupies a variety of sites from rolling benchlands to steep unstable slopes.

Vegetation. — Older trees are usually widely spaced and create a parklike appearance, but some seral stands are relatively dense. Normally, *Carex geyeri* dominates a depauperate forb layer. Beneath openings in the tree canopy a few forbs such as *Balsamorhiza, Geranium,* and *Lupinus* may be conspicuous. *Berberis repens* and *Ribes cereum* may be present in small patches, especially beneath large trees.

Symporicarpos oreophilus (SYOR) phase. — The *SYOR* phase occurs throughout the geographic range of the *PSME/CAGE* h.t. but usually appears at mid- to upper elevations (6,500 to 8,000 feet [1 980 to 2 440 m]) of the type. These sites often border the drier *PSME/SYOR* h.t. or a mountain shrub community that contains *Symphoricarpos oreophilus.*

The trees may be widely spaced creating an open-forest or savannah-like appearance. Usually *Pseudotsuga* is the only tree present. *Prunus virginiana* or *Artemisia tridentata* ssp. *vaseyana* often codominate the shrub layer with *Symphoricarpos.* These shrubs maintain a dominant layer in old growth stands.

Pinus ponderosa (PIPO) phase. — This phase occurs only in the western half of central Idaho and at the lower elevations (3,700 to 6,300 feet [1 130 to 1 920 m]) of the type. *Pinus ponderosa* often dominates the site and in some areas the *Pseudotsuga* reinvades very slowly. Other tree species are seldom present in large numbers. Seral undergrowths often contain *Amelanchier alnifolia, Purshia tridentata, Prunus virginiana,* or *Symphoricarpos oreophilus* in varying amounts. Following fire, *Ceanothus velutinus* may sprout from seed stored in the soil and develop a dominant layer that persists for several decades. Coverages of all these shrubs decrease with development of a *Pseudotsuga* canopy.

Carex geyeri (CAGE) phase. — This phase is most common and appears at mid- to upper elevations (5,300 to 8,700 feet [1 620 to 2 650 m]) of the type. It is common in the Challis section and in colder portions of the Southern Batholith section. *Pinus contorta* may dominate seral stands and sometimes *P. flexilis* or *P. albicaulis* are weakly represented. Shrubs are usually sparse, but *Prunus virginiana, Ribes cereum, Salix scouleriana,* or *Symphoricarpos oreophilus* may appear in seral undergrowths.

Soil. — The most common soil parent materials are granitics (appendix D). Other materials include quartzite, latite, andesite, rhyolite, and basalt. Soil textures vary accordingly from silty clay loam to very gravelly loamy sand. The pH ranges from 5.2 to 7.2 and averages 5.9. On most sites coverage of bare rock is less than 10 percent but a few sites have up to 60 percent. Exposed soil is usually less than 10 percent of the area but can reach 30 percent. Average litter depth on a site seldom exceeds 5 cm.

Productivity/Management. — Timber productivity ranges from low to high depending on the tree species present and the phase (appendix E). The *SYOR* phase appears least productive; a moderate site index for *Pinus ponderosa* gives the *PIPO* phase greatest productivity. Natural regeneration of *Pseudotsuga* is often sporadic and apparently requires some site protection. Artificial regeneration of *Pseudotsuga* assumes considerable risk of success. In the *PIPO* phase, the pine may regenerate more readily as a seral species than *Pseudotsuga.* The root system of the *Carex* is several times greater than the leafy portion and presents formidable competition to tree seedlings. Thus site preparation is needed even where spaces among the *Carex* might appear adequate for seedling establishment.

Forage production is generally low, and on steep slopes the gravelly soils are readily exposed by grazing animals. Destruction of the *Carex* sod may cause erosion scars that are difficult to revegetate. On some overgrazed sites, *Artemisia tridentata* now dominates the undergrowth. Burning or spraying the *Artemisia*

denies *Carex geyeri* seedlings shade and protection from trampling and jeopardizes recovery of the *Carex* sod.

In some areas, the *SYOR* phase provides important forage and cover for deer, elk, and blue grouse. The widely spaced trees and frequent ridge-line locations of this phase are well suited for birds of prey. Burning in the *PIPO* phase may increase forage for deer and elk.

Other studies. — The *PSME/CAGE* h.t. is recognized in Montana by Pfister and others (1977). Small amounts are also reported near the Idaho-Utah border (Henderson and others 1976, unpubl. ref.). In our area, Schlatterer (1972, unpubl. ref.) describes a Douglas-fir/elk sedge-snowberry community that resembles the *PSME/CAGE* h.t. Hall (1973) describes a "ponderosa pine-Douglas-fir-elk sedge community" in the Blue Mountains of Oregon that resembles our *PSME/CAGE* h.t., *PIPO* phase.

PSEUDOTSUGA MENZIESII/BERBERIS REPENS H.T. (*PSME/BERE;* DOUGLAS-FIR/OREGON GRAPE)

• *Berberis repens* phase (*BERE;* Oregon grape)

★ *Symphoricarpos oreophilus* phase (*SYOR;* mountain snowberry)

* *Carex geyeri* phase (*CAGE;* elk sedge)

Distribution. — This h.t. occurs mainly in southeastern Idaho and adjacent Utah but also extends into southern portions of central Idaho as a minor h.t. Here it is found primarily in mountain ranges that overlook either the Snake River Plain or Camas Prairie. It occupies a variety of aspects at lower to mid-elevations of the forested zone and ranges from 4,500 to 7,700 feet (1 370 to 2 350 m). Adjacent drier sites usually contain the *PSME/SYOR* h.t. or support nonforest communities.

Vegetation. — Usually *Pseudotsuga* is the only tree present but in central Idaho *Pinus ponderosa* may be present at the lower elevations. *Prunus virginiana* and *Symphoricarpos oreophilus* often dominate the undergrowth of seral stands. In stands that develop closed canopies, *Berberis repens* persists as the dominant shrub. *Arnica cordifolia, Smilacina racemosa,* and *Thalictrum occidentale* are the most common forbs and occasionally they develop high coverages.

Symphoricarpos oreophilus (SYOR) phase. — This phase is found mainly in the Boise Front Range and related mountains to the southeast. The sites often border nonforest communities dominated by *Prunus virginiana,* and *Symphoricarpos oreophilus.* Many openings remain between the trees, even in old growth stands, and the taller shrubs are never excluded (fig. 12).

Carex geyeri (CAGE) phase. — The *CAGE* phase appears mainly in the Southern Batholith section and has characteristics similar to *PSME/CAGE.* Some *Prunus, Amelanchier,* and *Symphoricarpos oreophilus* may codominate seral undergrowths, but *Berberis repens* with a layer of *Carex geyeri* dominates the undergrowth of older stands (fig. 13). As in *PSME/CAGE,* the tree canopy remains partially open.

Berberis repens (BERE) phase. — This phase, common throughout the range of the h.t., is restricted to leeward aspects where site protection and deep soils permit development of a closed tree canopy. Here the taller shrubs are eventually suppressed, leaving *Berberis repens* as the dominant shrub.

Soil. — Soil parent materials are mainly granitic, quartz monzonite, andesite, and basalt (appendix D). Soil textures range from loam to loamy sand and are sometimes gravelly. The pH ranged from 5.3 to 6.4 and averaged 5.8. Coverage of bare rock seldom exceeds 5 percent but in a few cases is as high as 25 percent. In the *SYOR* phase exposed boulders may account for 70 percent coverage. Areas of exposed soil are usually less than 10 percent and average litter depth on a site seldom exceeds 7 cm.

Productivity/Management. — Timber productivity is moderate to high (appendix E-2), but tree seedlings may require some protection from wind and sun. Although forage may be scarce, livestock use these sites for rest and shelter when grazing areas are nearby. Mule deer use the *BERE* phase for rest and shelter and the *SYOR* phase provides important browse in some areas.

Other studies. — The *PSME/BERE* h.t. is described in southern Idaho (Steele and others 1974, unpubl. ref.) and in northwestern Utah (Henderson and others 1976, unpubl. ref.). It is also reported from eastern Idaho-western Wyoming (Steele and others 1979, unpubl. ref.).

Figure 12. — Pseudotsuga menziesii/Berberis repens *h.t.,* Symphoricarpos oreophilus *phase on a convex ridge northwest of Rocky Bar, Idaho (7,100 feet [2 160 m] elevation).* Pseudotsuga menziesii *forms an open stand over a layer of* Symphoricarpos oreophilus, Prunus virginiana, *and* Berberis repens. *The dry southerly aspect and many large boulders prevent* Pseudotsuga *from developing a more dense stand.*

Figure 13. — Pseudotsuga menziesii/Berberis repens *h.t.,* Carex geyeri *phase on a southerly exposure west of Ketchum, Idaho (7,500 feet [2 280 m] elevation).* Pseudotsuga menziesii *forms a partially open stand over a moderate coverage of* Berberis repens *and* Carex geyeri.

PSEUDOTSUGA MENZIESII/CERCOCARPUS LEDIFOLIUS H.T. (*PSME/CELE;* DOUGLAS-FIR/MOUNTAIN MAHOGANY)

Distribution. — The *PSME/CELE* h.t. occurs mainly in the Challis and Open Northern Rockies sections from 6,000 to 8,100 feet (1 830 to 2 470 m) in elevation. It appears on various aspects at lower timberline where it often borders a *Cercocarpus* shrub community.

Vegetation. — Trees are often widely scattered. *Pseudotsuga* is usually the only tree present, but small amounts of *Pinus flexilis* are not uncommon. In parts of the Salmon River drainage, *Pinus ponderosa* may also appear in this h.t. A layer of *Cercocarpus* dominates the tree interspaces. Either *Symphoricarpos oreophilus* or *Agropyron spicatum* may form a subordinate layer.

Soil. — Soil parent materials vary widely and include limestone, shale, sandstone, pumice, quartz monzonite, and quartzite (appendix D). Soil textures are mostly loams or sandy loams and are often gravelly. The pH ranged from 5.5 to 7.9 and averaged 6.4. Coverage of bare rock reaches 40 percent on some sites and areas of bare soil can reach 30 percent. Average litter depth per site seldom surpasses 1.5 cm.

Productivity/Management. — Timber potential is low to very low based on limited data (appendix E-1), and tree regeneration is very sporadic. Livestock forage is sparse here, which is partly due to shrub density. In some areas this h.t. provides important browse and cover for elk, mule deer, antelope, and wild horses. As a result, it is an important breeding and hunting area for mountain lion. This h.t. also provides important nesting sites for the blue grouse, dusky flycatcher, rock wren, and American kestrel.

Other studies. — The *PSME/CELE* h.t. is also described in Utah and southeastern Idaho (Henderson and others 1976, unpubl. ref.) and in eastern Idaho-western Wyoming (Steele and others 1979, unpubl. ref.).

PSEUDOTSUGA MENZIESII/CALAMAGROSTIS RUBESCENS H.T. (*PSME/CARU;* DOUGLAS-FIR/PINEGRASS)

● *Calamagrostis rubescens* phase (*CARU;* pinegrass)

★ *Pinus ponderosa* phase (*PIPO;* ponderosa pine)

* *Festuca idahoensis* phase (*FEID;* Idaho fescue)

Distribution. — *PSME/CARU* has one of the broadest distributions of any h.t. in the *Pseudotsuga* series. The h.t. is found throughout most of central Idaho, but primarily in the Salmon Uplands and Southern Batholith sections. Usually it is found on upper slopes and ridges. It generally occurs at lower to mid-elevations of the forested zone, where it ranges from 4,100 to 7,900 feet (1 250 to 2 410 m). It occupies various cool, dry aspects having gentle to moderate relief.

Vegetation. — On the warmer sites of this h.t., *Pinus ponderosa* and *Pseudotsuga* often codominate the overstory. On cooler sites in gentle terrain, *Pinus contorta* may occur as a seral species. However, in much of this h.t., *Pseudotsuga* is the only tree present. *Calamagrostis rubescens* dominates the herb layer and often creates the main aspect (fig. 14). Seral shrubs may be present in various amounts as a reflection of past disturbance.

Festuca idahoensis (FEID) phase. — This minor phase occurs mainly in the Challis and Open Northern Rockies sections, but is also found near Stanley, Idaho. It represents a drier segment of the h.t. and generally borders nonforest communities between 6,800 and 7,600 feet (2 070 to 2 320 m). *Pseudotsuga* dominates the overstory along with an occasional *Pinus contorta*. *Calamagrostis rubescens* interspersed with *Festuca idahoensis* dominates the undergrowth. Forbs are usually sparse.

Figure 14. — Pseudotsuga menziesii/Calamagrostis rubescens *h.t.,* Calamagrostis rubescens *phase on a broad northerly exposure northwest of Spencer, Idaho (7,500 feet [2 290 m] elevation). A pure stand of all-age* Pseudotsuga menziesii *dominates a layer of* Calamagrostis rubescens. Arnica cordifolia *and* Antennaria racemosa *are the predominant forbs.*

Pinus ponderosa (PIPO) phase. — The *PIPO* phase occurs throughout much of the Southern Batholith, Wallowa-Seven Devils, and Salmon Uplands sections. It represents the warm, low elevation (4,100 to 6,500 feet [1 250 to 1 980 m]) segment of the h.t. with *Pinus ponderosa* often dominating or codominating the overstory. Because these stands are fairly open, the pine is seldom excluded. Occasionally *Pinus contorta* is present. Occurrence and coverage of *Amelanchier, Prunus,* and *Purshia* are higher in this phase than in the *CARU* or *FEID* phase.

Calamagrostis rubescens (CARU) phase. — This, the predominant phase in the Challis and Open Northern Rockies sections, also extends westward across central Idaho. This phase represents the cool, upper elevation (6,400 to 7,900 feet [1 950 to 2 410 m]) segment of the h.t. *Pinus contorta* is a major seral tree but it does not occur everywhere within this phase. *Symphoricarpos oreophilus* is the most common shrub, but on some sites *Ceanothus velutinus* may appear following fire and persist for several decades.

Soil. — Granitics, quartzite, quartz monzonite, trachyte, andesite, and basalt are the common soil parent materials (appendix D). Most soil textures range from loam to loamy sand and many are gravelly. Soil pH ranged from 5.5 to 7.1 and averaged 6.2. Coverages of bare rock are usually less than 5 percent but may sometimes reach 50 percent. Areas of bare soil rarely exceed 5 percent. Average litter depth on a site is seldom more than 6 cm.

Productivity/Management. — Timber production is low to moderate in the *CARU* phase and moderate to high in the *PIPO* phase (appendix E-2). When the overstory is reduced, the *Calamagrostis* may develop a thick sod. To establish conifers, the sod often requires special treatment, as outlined under the *Pseudotsuga* series description. When present, *Pinus ponderosa* or *P. contorta* can be regenerated in openings that receive full sunlight if the site is adequately prepared and protected from grazing animals. Where *Pseudotsuga* is the only conifer adapted to the site, its seedlings often require additional protection from wind and sun.

If these sites are burned, *Ceanothus velutinus* may sprout from seed stored in the soil and form a dominant layer for several decades. The amount of seed stored in the soil varies. Lyon (1971) describes succession on a burned area in this h.t. that contained a large amount of *Ceanothus* seed.

Seral stands that produce *Ceanothus, Salix,* and *Populus tremuloides* are very important to deer and elk. In some areas the sites may be important for elk calving. Old-growth stands are important nesting sites for the Steller's jay, western tanager, and pine siskin. Livestock make some use of these sites if on gentle terrain, but forage production tends to be low.

Other studies. — In studies of adjacent areas, R. and J. Daubenmire (1968) describe a PSME/CARU h.t. in northern Idaho and eastern Washington. They also note its

occurrence in the Wallowa Mountains of eastern Oregon and the eastern foothills of the Cascade Mountains in Washington. *PSME/CARU* is also reported from Montana (Pfister and others 1977), and eastern Idaho-western Wyoming (Steele and others 1979, unpubl. ref.). The lower elevation portions of Hall's (1973) "mixed conifer-pinegrass" communities in eastern Oregon appear comparable to our *PSME/CARU* h.t., *PIPO* phase.

PSEUDOTSUGA MENZIESII/OSMORHIZA CHILENSIS H.T. (*PSME/OSCH;* DOUGLAS-FIR/MOUNTAIN SWEET-ROOT)

Distribution. — This is a minor h.t. in central Idaho that has its main distribution south of the Snake River Plains. It usually appears on the leeward slopes of ridges that are adjacent to the Snake River Plain or related deserts. Most sites occur from 5,300 to 7,400 feet (1 620 to 2 260 m). Adjacent warmer slopes often support nonforest communities.

Vegetation. — Usually *Pseudotsuga* is the only conifer present. *Populus tremuloides* and sometimes *Pinus contorta* may dominate seral stands. Species from adjacent mountain shrub communities may also invade disturbed sites. *Osmorhiza chilensis* usually dominates the forb layer. When a *PSME/CARU* or *PSME/CAGE* h.t. is nearby on drier sites, the *Calamagrostis* or *Carex* may be well represented, especially in younger stands.

Soil. — Soil parent materials include granitics, andesite, rhyolite, and basalt (appendix D). Textures are mainly loams or sandy loams; a few are gravelly. Soil pH ranged from 5.5 to 6.6 and averaged 5.8. Areas covered by bare soil or rock are less than 5 percent. Litter depths seldom exceed 5.5 cm.

Productivity/Management. — Timber productivity is moderate to high (appendix E-2). *Pseudotsuga* regenerates most easily in the shade of older trees and is often the only conifer adapted to the site. If present, *Populus tremuloides* can quickly dominate cleared areas in this h.t.; otherwise, shrubs from adjacent communities will dominate the clearings and suppress conifer seedlings. Pocket gophers are sometimes numerous and may destroy young trees. Livestock often use these sites as resting areas but find little forage here.

Big game use is normally light but may increase in early seral stages. A few sites provide important resting areas for mule deer.

Other studies. — *PSME/OSCH* is also described from southeastern Idaho and adjacent Utah (Steele and others 1979, unpubl. ref.; Henderson and others 1976, unpubl. ref.).

PSEUDOTSUGA MENZIESII/SPIRAEA BETULIFOLIA H.T. (*PSME/SPBE;* DOUGLAS-FIR/WHITE SPIRAEA)

• *Pinus ponderosa* phase (*PIPO;* ponderosa pine)

★ *Spiraea betulifolia* phase (*SPBE;* white spiraea)

* *Calamagrostis rubescens* phase (*CARU;* pinegrass)

Distribution. — *PSME/SPBE* occurs throughout much of central Idaho but is most prevalent in the Southern Batholith section. Usually, *PSME/SPBE* occupies dry southerly exposures and occurs from 3,300 to 8,100 feet (1 010 to 2 470 m). It exists in a variety of conditions, from steep, unstable slopes to gentle, rolling terrain.

Vegetation. — Overstory composition varies between the phases noted below. Normally, *Spiraea betulifolia* dominates a low shrub layer but sometimes *S. pyramidata* occurs in its place. *Calamagrostis rubescens* or *Carex geyeri* often form a layer beneath the *Spiraea.*

Pinus ponderosa (PIPO) phase. — This phase, occurring mainly in the Wallowa-Seven Devils and Southern

Figure 15. — Pseudotsuga menziesii/Spiraea betulifolia *h.t.,* Spiraea betulifolia *phase on a northerly exposure northeast of Pine, Idaho (6,860 feet [2 090 m] elevation).* Pseudotsuga menziesii *and a few* Pinus contorta *codominate a layer of* Spiraea betulifolia. *This site is apparently too cool to support* Pinus ponderosa.

Batholith sections, represents the warm, lower elevations (3,300 to 6,000 feet [1 010 to 1 830 m]) of the h.t. Usually *Pinus ponderosa* is present as a long-lived seral species that is seldom excluded by *Pseudotsuga*. *Amelanchier* and *Salix* are also common in this phase.

Calamagrostis rubescens (CARU) phase. — The *CARU* phase is found in the Challis and Salmon Uplands sections and higher elevations of the Southern Batholith section and extends eastward into western Wyoming. This phase represents the cool, upper elevations (6,000 to 7,900 feet [1 830 to 2 410 m]) of the h.t. *Pinus contorta* is more common in this phase than in the other phases, and *Symphoricarpos oreophilus* is a common shrub. The *Calamagrostis* creates a conspicuous layer in most stands, resembling the *PSME/CARU h.t.*

Spiraea betulifolia (SPBE) phase. — This phase occurs in higher elevations of the Southern Batholith section and in the Challis and Salmon Uplands sections and also extends eastward into Wyoming. It occupies the mid- to upper segment (5,200 to 8,100 feet [1 590 to 2 470m]) of the h.t. Here the sites are too cool for *Pinus ponderosa* and apparently the substrates are unsuitable for heavy *Calamagrostis* development. Usually *Pseudotsuga* is the only tree growing on these sites (fig. 15), but occasionally *Pinus contorta, P. flexilis* or *Populus tremuloides* is present. *Symphoricarpos oreophilus* and *Berberis repens* are the most common associates of *Spiraea*.

Soil. — Soil characteristics appear to vary between phases (appendix D). In the *PIPO* phase, soil parent materials are mostly granitics, basalt, and some andesite. Textures range from loamy sand to clay loam, but most are loams and a few are gravelly. Soil pH ranged from 5.4 to 6.4 and averaged 5.9. Areas of bare rock reach 60 percent and bare soil 30 percent, although most sites have less than 5 percent of either surface. Average litter depth on a site can attain at least 6.5 cm.

Soil parent materials in the *CARU* phase are mostly quartzite and some latite. The textures vary from sandy loam to loam and most are gravelly. Soil pH ranged from 6.2 to 6.7 and averaged 6.4. Coverages of bare rock are less than 5 percent and areas of bare soil less than 2 percent. Litter depths seldom exceed 3.5 cm.

The *SPBE* phase has the most variable soils. Parent materials include granitics, quartzite, diorite, dacite, quartz monzonite, and andesite. Textures vary from sandy loam to loam and most are gravelly to very gravelly. Coverages of bare rock vary and may reach 40 percent. The pH ranged from 5.7 to 7.7 and averaged 6.6. Areas of bare soil are usually less than 5 percent. Average litter depth seldom exceeds 3.5 cm.

Productivity/Management. — Timber productivity is low to moderate in the *SPBE* phase and moderate to high in the *PIPO* phase (appendix E-2). If present, *Pinus ponderosa* or *P. contorta* are usually best suited for regenerating the stand. Where *Pseudotsuga* is the only species suitable for timber, the seedlings may need protection from wind and sun. If a layer of *Calamagrostis* or *Carex* is present, the site may need careful preparation for adequate stocking. In most areas livestock use the sites only lightly, but big game use them frequently. Some sites provide important forage and cover for elk and mule deer. Deer may also use these areas for fawning. This h.t. provides important nesting sites for the Steller's jay, red-breasted nuthatch, and Cooper's hawk. In the *PIPO* phase, wild turkey may roost in the large pines and feed on the seeds.

Other studies. — In Montana, Pfister and others (1977) describe the *PSME/SPBE* h.t. but assign stands with high coverages of *Calamagrostis* or *Carex* to other h.t.'s. From eastern Washington, R. and J. Daubenmire (1968) report one stand in their *PSME/SYAL* h.t. that conforms to our *PSME/SPBE* h.t. Steele and others (1979 unpubl. ref.) also describe this h.t. in eastern Idaho.

PSEUDOTSUGA MENZIESII/SYMPHORICARPOS ALBUS H.T. (*PSME/SYAL*; DOUGLAS-FIR/COMMON SNOWBERRY)

•*Pinus ponderosa* phase (*PIPO;* ponderosa pine) ★*Symphoricarpos albus* phase (*SYAL;* common snowberry)

Distribution. — *PSME/SYAL* occurs mainly in the Wallowa-Seven Devils, Salmon Uplands, and Southern Batholith sections.

It occupies warm, dry slopes and benches and ranges from 3,200 to 7,100 feet (980 to 2 160 m) at lower to mid-elevations of the forested zone.

Vegetation. — Overstories vary between the phases noted below. Undergrowths are usually dominated by a layer of *Symphoricarpos albus*, often accompanied by *Spiraea betulifolia* and *Rosa* spp. On many sites *Calamagrostis rubescens* or *Carex geyeri* forms a layer beneath the shrubs.

Pinus ponderosa (PIPO) phase. — This is the most common phase in central Idaho. It occurs from 3,200 to 6,200 feet (980 to 1 890 m) and represents the warmer segment of the h.t. *Pinus ponderosa* is a long-lived seral dominant that is seldom excluded by *Pseudotsuga*. Occasionally *Pinus contorta* is also present.

Symphoricarpos albus (SYAL) phase. — This phase appears mainly east of the study area but it extends westward in the colder segment of the h.t. at elevations from 5,100 to 7,100 feet (1 560 to 2 160 m). *Pseudotsuga* is usually the only conifer on these sites, but seral stands may contain *Populus tremuloides*.

Soils. — Most of our sample stands occur on granitics, quartz monzonite, or basalt (appendix D). Soil textures vary from sandy loam to clay loam and some are gravelly to very gravelly. The pH ranges from 5.5 to 7.0 and averages 6.4 Areas of bare rock or bare soil seldom exceed 5 percent. Average litter depth can reach 8.7 cm.

Productivity/Management. — Timber productivity is moderate to high (appendix E-1). In the *PIPO* phase, *Pinus ponderosa* is usually the conifer most suitable for restocking the site. It grows best in openings that receive full sunlight. When present, *Calamagrostis rubescens* also responds to increased sunlight and can form a dense sod that retards conifer reproduction. In the *SYAL* phase, *Pseudotsuga* is usually the only conifer well adapted to these sites. Here, the existing stand must be managed carefully to protect *Pseudotsuga* seedlings from severe wind and sun.

Livestock usually find low amounts of forage in this h.t.; but may sometimes congregate because of the gentle terrain. In some areas, the seral shrubs provide important browse for elk, whitetail deer, or mule deer. In the *PIPO* phase, ruffed grouse may use these sites year round and wild turkey may roost in the large pines and feed on pine seeds.

Other studies. — R. and J. Daubenmire (1968) described the *PSME/SYAL* h.t. in northern Idaho and eastern Washington but included one stand that fits our *PSME/SPBE* h.t. Pfister and others (1977) describe *PSME/SYAL* in Montana. It is also reported from

eastern Idaho and western Wyoming (Cooper 1975; Steele and others 1979, unpubl. ref.). In eastern Oregon, a portion of Hall's (1973) "ponderosa pine-Douglas-fir-snowberry-oceanspray" community is apparently similar to our PSME/SYAL h.t., PIPO phase.

PSEUDOTSUGA MENZIESII/VACCINIUM GLOBULARE H.T. (*PSME/VAGL;* DOUGLAS-FIR/ BLUE HUCKLEBERRY)

Distribution. — *PSME/VAGL* is an incidental type, occurring mainly in Montana and eastern Idaho. Small amounts appear in the Southern Batholith and Salmon Uplands sections.

Vegetation. — *Pinus ponderosa* and *P. contorta* are the common seral conifers. *Vaccinium globulare* forms a dominant layer in the undergrowth. *Spiraea betulifolia* and *Calamagrostis rubescens* are common associates of the *Vaccinium*.

Productivity/Management. — If present, *Pinus ponderosa* or *P. contorta* should regenerate wherever the tree canopy is removed and a seedbed is available. *Pseudotsuga* seedlings may benefit from a light tree canopy, but the undergrowth of shrubs and grass can impede their establishment. In summer and fall, elk and deer may seek food and cover on these sites and the berry crops attract bears, grouse, and humans.

Other studies. — Pfister and others (1977) describe *PSME/VAGL* in Montana as a major h.t. Cooper (1975) describes it in eastern Idaho where it is less common.

PSEUDOTSUGA MENZIESII/ACER GLABRUM H.T. (*PSME/ACGL;* DOUGLAS-FIR/MOUNTAIN MAPLE)

★ *Symphoricarpos oreophilus* phase (*SYOR;* mountain snowberry)

• *Acer glabrum* phase (*ACGL;* mountain maple)

Distribution. — *PSME/ACGL* extends across central Idaho to western Wyoming and southeastern Idaho. However, it appears to be absent from the Wallowa-Seven Devils and Salmon Uplands sections. It is a minor h.t. that usually appears on steep northerly aspects at mid-elevations of the forested zone. It was found from 4,800 to 8,000 feet (1 460 to 2 440 m) elevation.

Vegetation. — Overstories vary between the phases noted below. *Acer glabrum* is usually well represented and on steep slopes forms large, spreading shrubs in old-growth stands. On gentle slopes deer and elk may browse the entire shrub and prevent development of an *Acer* canopy. In seral condition, tall-to-medium shrubs often dominate the site for several decades. Shrub species vary between phases. This h.t. sometimes borders the *Abies lasiocarpa* series and occasionally includes isolated *Abies*.

Symphoricarpos oreophilus (SYOR) phase. — The *SYOR* phase is found mainly in the Lemhi Mountains and occasionally westward to the Wood River. Elevations range from 6,700 to 8,000 feet (2 040 to 2 440 m). Although it represents the cool, dry portion of the h.t., it usually indicates some of the most moist uplands in the area and borders a *PSME/SYOR* or *PSME CELE* h.t. on drier sites. Small amounts of *Pinus flexilis* are common, but *Pseudotsuga* is the only tree capable of dominating the site. *Acer glabrum* is usually well represented in a sparse layer of medium-to-tall shrubs. Of these, *Symphoricarpos oreophilus* and *Ribes cereum* are most common.

Acer glabrum (ACGL) phase. — The *ACGL* phase appears mainly in the Southern Batholith section but extends eastward to about the Wood River. It represents the warmer segment of the h.t. and occurs from 4,800 to 6,800 feet (1 460 to 2 070 m) elevation. Conceptually, this phase would support *Abies grandis* if this species had a broader distribution in our area. On some sites, *Pinus ponderosa* is present and may codominate with *Pseudotsuga.* In seral stands *Amelanchier, Salix,* and *Prunus* are common associates of *Acer glabrum. Penstemon wilcoxii* and *Arenaria macrophylla* are common in the forb layer.

Soils. — Soil characteristics vary between phases (appendix D). Soils in the *SYOR* phase are derived mostly from calcareous sedimentaries and a few from quartzite. The textures are mostly loams or silt-loams and are usually gravelly to very gravelly. Areas of bare rock often reach 15 percent, but bare soil seldom exceeds 5 percent. Average litter depth per site can approach 8 cm.

Soils in the *ACGL* phase are derived from quartz monzonite, diorite, granitics, basalt, and occasionally sedimentaries. Textures are mostly loams to sandy loams and a few are gravelly. Soil pH ranges from 5.9 to 6.6 and averages 6.3. Coverage of bare rock can reach 15 percent but is usually less than 5 percent.

Areas of bare soil seldom exceed 5 percent. Average litter depth per site can approach 10 cm.

Productivity/Management. — Timber productivity is moderate to very high in the *ACGL* phase (appendix E-2). In openings, *Pinus ponderosa,* if present, grows well and regenerates easily; however, a dense layer of shrubs may develop and suppress conifer seedlings for several decades. Artificial regeneration of *Pseudotsuga* can be successful with adequate site preparation (Kittams and Ryker 1975). Part of Lyon's (1971) study of succession after fire included this h.t. and probably this phase.

In the *SYOR* phase, timber potential is low to moderate (appendix E-2). *Pseudotsuga* is the only suitable timber species for these sites and its regeneration may be slow to establish. Overstory removal will stimulate the growth of shrubs, which may suppress conifer seedlings.

In both phases, livestock find little forage in mature stands but may seek shelter from sun and insects. In most areas, however, livestock seldom use these sites because adjacent areas provide more gentle slopes and better forage.

PSME/ACGL sites may be important to wildlife, depending upon location and stage of succession. The seral shrubs provide important forage and cover for elk and mule deer but snow depths usually prevent winter use. The sites may provide important habitat for ruffed grouse most of the year and for blue grouse in summer and fall.

Other studies. — Schlatterer (1972, unpubl. ref.) first recognized *PSME/ACGL* in his "Douglas-fir/tall shrubs" community. In southeastern Idaho, Henderson and others (1976, unpubl. ref.) describe a *PSME/ACGL* h.t. which has been classified as the *Pachistima myrsinites* phase (Steele and others 1979, unpubl. ref.).

PSEUDOTSUGA MENZIESII/PHYSOCARPUS MALVACEUS H.T. *(PSME/PHMA;* DOUGLAS-FIR/NINEBARK)

• *Pinus ponderosa* phase *(PIPO;* ponderosa pine)
★ *Pseudotsuga menziesii* phase *(PSME;* Douglas-fir)

Distribution. — In central Idaho, *PSME/PHMA* is most common in the Southern Batholith, Salmon Uplands, and Wallowa-Seven Devils sections. It occurs most often on relatively steep slopes that have northerly aspects. This h.t. ranges from 3,100 to 7,100 feet (950 to 2 160 m) and represents warm, mild environments at lower to mid-elevations of the forested zone. It may also extend to lower timberline on steep north slopes.

Vegetation. — *Pinus ponderosa* is the only major seral conifer found in *PSME/PHMA.* Its occurrence varies between phases noted below. *Physocarpus* forms a patchy to uniform layer but generally dominates the undergrowth. *Amelanchier* is the most common associate of *Physocarpus.* Various forbs occur wherever there is sufficient light. On some sites, *Calamagrostis rubescens* or *Carex geyeri* form a conspicuous layer.

Calamagrostis rubescens (CARU) phase. — In central Idaho, this incidental phase occurs occasionally in the Salmon Uplands and Southern Batholith sections. *Pinus ponderosa* is a major seral species and often codominates with *Pseudotsuga. Physocarpus,* though well represented, appears as scattered shrubs or shrub patches and the prevailing undergrowth is *Calamagrostis rubescens* or *Carex geyeri* (fig. 16). These sites appear transitional to a *PSME/CARU* h.t. and should respond similarly to management.

Pinus ponderosa (PIPO) phase. — The *PIPO* phase occurs throughout the Southern Batholith, Salmon Uplands, and Wallowa-Seven Devils sections. Usually, *Pinus ponderosa* is a long-lived seral species but it

Figure 16. — Pseudotsuga menziesii/Physocarpus malvaceus *h.t.*, Calamagrostis rubescens *phase on a steep, southwest exposure east of Grangeville, Idaho (3,150 feet [960 m] elevation).* Pseudotsuga menziesii *and* Pinus ponderosa *codominate patches of* Physocarpus malvaceus *and* Calamagrostis rubescens. *This phase is uncommon in the study area.*

does not always dominate seral stands. *Physocarpus* generally forms a nearly complete cover except beneath large trees. *Spiraea betulifolia* and *Berberis repens* are usually present in this phase.

Pseudotsuga menziesii (PSME) phase. — This phase appears mainly in the Challis and Open Northern Rockies sections and locally along the northern edge of the Snake River Plains. Usually *Pseudotsuga* is the only tree on these sites. *Physocarpus* varies from nearly complete to a patchy cover. *Symphoricarpos oreophilus* commonly associates with the *Physocarpus*.

Soil. — Soil parent materials are mostly granitics or basalt and occasionally quartzite or quartz monzonite (appendix D). Soil textures vary from silty clay loam to sandy loam and a few are gravelly to very gravelly. Soil pH ranges from 5.5 to 6.9 and averages 6.4. Coverages of bare rock are usually less than 5 percent but can reach 60 percent in some cases. Areas of bare soil are usually less than 5 percent. Average litter depth on a site can reach at least 11 cm.

Productivity/Management. — Timber productivity is moderate in the *PSME* and moderate to high in the *PIPO* phase. In much of the *PIPO* and *CARU* phases, *Pinus ponderosa* is a vigorous seral species and regenerates easily where it receives full sunlight. In the *PSME* phase, *Pseudotsuga* is the only tree adapted to the site and requires careful stand manipulation for successful regeneration. Removing the tree canopy may stimulate shrub development and retard growth of tree seedlings.

Livestock seldom graze these sites unless severe disturbance has caused invasion of grasses and forbs.

Big game frequent these areas; amount of use varies with stage of succession and location of site. In some wintering areas, these sites are important for elk, especially if seral shrubs are present and, in a few areas, moose utilize the forage and cover year round. Along the Salmon River, bighorn sheep use these sites for forage, cover, and escape. Whitetail deer, mule deer, and black bear also use the heavy cover. Ruffed grouse and, to a lesser extent, blue grouse may use these sites much of the year. When large *Pinus ponderosa* are present, wild turkeys may forage and roost here and flying squirrels are known to use the old, hollow pines. This h.t. is also considered important for the pileated woodpecker, mountain chickadee, red-breasted nuthatch, and pygmy owl.

Other studies. — This h.t. has been reported by R. and J. Daubenmire (1968), Hall (1973), Pfister and others (1977), Cooper (1975), Henderson and others (1976, un-

publ. ref.) and Steele and others (1979, unpubl. ref.). Widespread distribution results in differences in composition which are partially differentiated by the phase designations.

PSEUDOTSUGA MENZIESII/LINNAEA BOREALIS H.T. (*PSME/LIBO;* DOUGLAS-FIR/TWINFLOWER)

Distribution. — *PSME/LIBO* occurs as an incidental type in the North Fork of the Salmon River drainage. From here it extends north and east into Montana where it becomes more prevalent.

Vegetation. — In our study area, seral stands may contain *Pinus contorta* or *P. ponderosa.* Undergrowths normally contain a layer of *Calamagrostis rubescens,* with *Linnaea* throughout. *Symphoricarpos albus* and *Vaccinium globulare* may also form conspicuous layers, which denote different phases in Montana (Pfister and others 1977).

Productivity/Management. — Timber productivity should be moderate in our area. If present, *Pinus contorta* or *P. ponderosa* should regenerate in openings that receive full sunlight. However, when the tree canopy is removed *Calamagrostis* may increase and create a need for special site preparation.

Other studies. — *PSME/LIBO* is described more fully in Montana (Pfister and others 1977) but is not reported elsewhere.

PSEUDOTSUGA MENZIESII/VACCINIUM CAESPITOSUM H.T. (*PSME/VACA;* DOUGLAS-FIR/DWARF HUCKLEBERRY)

Distribution. — *PSME/VACA* is an incidental h.t. in the Southern Batholith and Salmon Uplands sections. It also occurs in the South Fork of the Clearwater drainage in north Idaho, but the bulk of its distribution lies in Montana.

Vegetation. — *Pinus contorta* and *P. ponderosa* are seral species in this h.t. *Vaccinium caespitosum* is normally associated with *Arctostaphylos uva-ursi, Calamagrostis rubescens,* and *Carex geyeri.*

Productivity/Management. — Timber productivity should be moderate. *Pinus ponderosa* and *P. contorta* can regenerate in openings that receive ample sunlight. If *Calamagrostis rubescens* is present in large amounts, the sod may need to be broken for successful tree regeneration.

Other studies. — Pfister and others (1977) describe *PSME/VACA* in Montana, but it has not been reported elsewhere.

Picea engelmannii Series

Distribution. — Along streams with cool air drainage, *Picea engelmannii* and *Abies lasiocarpa* often extend into lower elevations of the *Pseudotsuga* zone. In the Challis and Open Northern Rockies sections, *Picea* exceeds the warm limits of *Abies* and forms climax stands on moist slopes and along drainage ways. This situation is especially common in the Lemhi and Beaverhead Mountains. It becomes more prevalent in Montana where *Picea* displays an infusion of *Picea glauca* genes in the population (Pfister and others 1977; Ogilvie 1962). Daubenmire (1974) also reports *Picea* hybrids east of the Continental Divide from Canada to Wyoming, but evidence of *Picea glauca* traits is scarce in our area.

Vegetation. — On very wet sites, *Picea engelmannii* appears as the climax dominant, often replacing seral *Pinus contorta.* Here, *Abies lasiocarpa* is often present, usually as unthrifty seedlings or saplings incapable of replacing *Picea.* Undergrowths vary by h.t. and generally reflect wet substrates with poor aeration.

On drier sites, *Picea* codominates with *Pseudotsuga* but appears incapable of excluding it. Small amounts of *Pinus flexilis* are sometimes present. Undergrowths are very depauperate — often consisting of a few scattered shrubs or forbs — with mosses, lichens, and duff attaining the highest coverages.

Soil. — Soil characteristics at the series level are extremely variable and are described at the h.t. level where they are fairly uniform.

Fire. — Stand structure and species composition suggest that fire has altered these plant communities. Some charcoal is usually found on these sites, but the small amounts suggest that fire frequents these sites less often than on contiguous slopes. Also, some charcoal on the bottomland sites may have been transported by gravity or water. In general, undergrowths in this series normally appear either too wet or too depauperate to burn well, but the trees could maintain a hot fire that was generated elsewhere.

Productivity/Management. — Timber productivities vary from low to high. The highest productivities are streamside locations that are seldom conducive to intensive timber management. Also, these wet sites are easily degraded by livestock and machinery but can be important to deer, elk, moose, and bear.

PICEA ENGELMANNII/HYPNUM REVOLUTUM H.T. *(PIEN/HYRE;* SPRUCE/HYPNUM)

Distribution. — This h.t. occurs mainly in the southern half of the Lemhi and Beaverhead ranges and in western Wyoming. In all cases, these sites occur on steep, northerly aspects where snow apparently accumulates in winter and persists in the spring. Though well drained and very dry, these are usually the most moist upland sites in the area. They tend to represent lower to mid-elevations of a very narrow forest zone and range from 7,300 to 8,100 feet (2 230 to 2 470 m).

Vegetation. — *Pseudotsuga* predominates in most stands, with lesser amounts of *Picea* occurring throughout. In old-growth stands, regeneration of the two trees is often equal. *Pinus flexilis* usually appears in small amounts. Shrubs, forbs, and grasses are notably sparse but, if present, usually include *Juniperus communis, Shepherdia canadensis, Symphoricarpos oreophilus,* and *Arnica cordifolia.* Unless disturbed, a thin layer of moss, *Hypnum revolutum,* dominates the undergrowth (fig. 17). Other mosses may be scarce, although *Dicranowiesia crispula* and the lichen, *Cladonia fimbriata,* are usually present on rotting wood. The foliose lichen, *Peltigera rufescens,* is usually evident throughout the stand.

Soil. — Soils are gravelly and derived mostly from calcareous shale and sandstone, and limestone (appendix D). In our few samples, soil pH ranged from 7.7 to 8.4 and averaged 8.0. Coverages of bare rock are less than 5 percent and areas of bare soil less than 1 percent. Average litter depth per site seldom exceeds 4 cm.

Productivity/Management. — Timber productivity is low (appendix E-2). *Pseudotsuga* and especially *Picea* grow slowly and their diameter increments decline at a relatively early age. Consequently, gains from thinning may be marginal. Tree regeneration may be sporadic and timber harvests should remove trees according to the pattern and frequency of regeneration observed in the stand. Big game and livestock find very little forage here but may use these sites for cover.

Other studies. — *PIEN/HYRE* has been described in western Wyoming (Steele and others, 1979 unpubl. ref.). It appears related to the *Picea/Senecio streptanthifolius* h.t. in Montana (Pfister and others 1977).

PICEA ENGELMANNII/GALIUM TRIFLORUM H.T. *(PIEN/GATR;* SPRUCE/SWEETSCENTED BEDSTRAW)

Distribution. — *PIEN/GATR* is an incidental h.t. in east-central Idaho. It is most common in Montana and occurs in western Wyoming. Typically, these sites occur on alluvial terraces or bottomlands and sometimes appear on slopes associated with seeps.

Vegetation. — Normally *Picea* dominates the stand. Occasionally *Abies lasiocarpa* achieves a minor foothold and small amounts of *Pinus contorta* may invade following disturbance. Undergrowths vary considerably as a reflection of site history and adjacent plant communities; however, *Galium triflorum* and *Actaea rubra* are common throughout the h.t. *Senecio triangularis* and *Streptopus amplexifolius* may occur in the wetter portions.

Productivity/Management. — Timber productivity is probably moderate to high. *Picea* and sometimes *Pinus contorta* grow well here, but the streamside locations may restrict timber harvest. Machinery and livestock easily disrupt the soil and may expose high water tables. Protection of soil and water resources may outweigh other values.

Other studies. — *PIEN/GATR* is described in Montana (Pfister and others 1977) and in western Wyoming (Cooper 1975; Steele and others 1979, unpubl. ref.).

PICEA ENGELMANNII/CAREX DISPERMA H.T. *(PIEN/CADI;* SPRUCE/SOFT LEAVED SEDGE)

Figure 17. — Picea engelmannii/Hypnum revolutum *h.t. on a north exposure in the Beaverhead Mountains northeast of Blue Dome, Idaho (8,100 feet [2 470 m] elevation).* Pseudotsuga menziesii *is the dominant tree, but the regeneration is* Picea engelmannii. Pinus flexilis *is scattered throughout the stand; the moss,* Hypnum revolutum, *forms the predominant undergrowth layer.*

Distribution. — *PIEN/CADI* occurs mainly in the Challis and Open Northern Rockies sections, from 6,200 to 7,800 feet (1 890 to 2 380 m) in elevation. It is a minor h.t. found on stream terraces near the lower limits of *Abies lasiocarpa.* It usually occurs in patches or strips that seldom exceed 1 acre (0.4 ha) of continuous habitat.

Vegetation. — *Picea engelmannii* usually dominates the site. Lesser amounts of *Pinus contorta* may be present as a seral species. In some areas, *Abies lasiocarpa* seedlings and saplings will grow here, but are usually short lived and incapable of replacing *Picea.* In good condition, these sites are covered with a carpet of *Carex disperma* (fig. 18). Numerous wet-site herbs, graminoids, and shrubs may be present but seldom dominate (appendix C). Mosses often form a pronounced layer; characteristic species are *Aulocomnium palustre, Amblystegium juratzkanum,* and *Tetraphis pellucida* (Steele 1974).

Soil. — Most substrates in this h.t. consist of a deep organic layer associated with a high water table (appendix D). The pH ranged from 4.9 to 6.2 and averaged 5.6. Areas of bare rock and bare soil are negligible.

Productivity/Management. — Timber productivity is moderate (appendix E-2). Although relatively small in area, these sites should be recognized when planning access to and use of adjacent h.t.'s. Livestock and machinery can easily destroy the *Carex* mat and leave the substrate exposed to erosion. Tree regeneration may depend on the raised microsites of hummocks and fallen logs. Partial cutting in old-growth stands may subject remaining large trees to windthrow.

Livestock find little forage here but use these cool, wet sites for resting and watering. Elk, moose, and black bear use these sites for wallows. *PIEN/CADI* also provides important nesting sites for the MacGillivray's warbler, American robin, and warbling vireo.

Figure 18. — Picea engelmannii/Carex disperma *h.t. on an alluvial terrace in the Lemhi Mountains southwest of Lemhi, Idaho (6,850 feet [2 090 m] elevation).* Picea engelmannii *has replaced a previous stand of* Pinus contorta. *The fallen stems of* Pinus contorta *have protected the carpet of* Carex disperma *from destruction by livestock.*

Other studies. — This h.t. is also noted in western Wyoming (Steele and others 1979, unpubl. ref.).

PICEA ENGELMANNII/EQUISETUM ARVENSE H.T. *(PIEN/EQAR;* SPRUCE/COMMON HORSETAIL)

Distribution. — *PIEN/EQAR* is an incidental h.t. in the Challis and Open Northern Rockies sections. It becomes more common eastward in Montana and western Wyoming. These sites usually occur on stream terraces and very wet benches; rarely do they occur on sloping seeps. In most cases they occupy a limited area.

Vegetation. — Usually *Picea engelmannii* is the dominant tree. *Pinus contorta* may be present in seral stands and sometimes *Abies lasiocarpa* appears in minor amounts. *Equisetum arvense* usually dominates a rich undergrowth of wet-site forbs and graminoids. A wide assortment of subalpine species grows on the raised microsites. Mosses often form a notable layer here.

Productivity/Management. — Timber potentials are probably moderate to high. *Picea* grows well here, but timber harvest is limited by the easily destroyed substrates and windthrow potential of existing trees. Big game seek the lush forbs on these sites and may use the area for wallows. Domestic stock will graze here as other sites become drier in late summer, but concentrated use can easily destroy the plant cover.

Other studies. — *PIEN/EQAR* is described in Montana (Pfister and others 1977) and in eastern Idaho and western Wyoming (Cooper 1975; Steele and others 1979, unpubl. ref.).

Abies grandis Series

Distribution. — *Abies grandis* grows primarily in the western third of central Idaho, but it also occurs sporadically eastward in the Salmon Uplands section to Colson Creek near Shoup, Idaho. Its known southern limit is in Alder Creek, south of Garden Valley.

Daniels (1969) showed that most *Abies grandis* in central Idaho are intergrades between *A. grandis* and *A.*

concolor. This zone of intergradation extends from central Idaho across eastern Oregon to northern California. Although individual trees may conform to either species (Hitchcock and Cronquist 1973), Daniels (1969) found that the majority of the population in central Idaho had a stronger resemblance to *A. grandis* than *A. concolor.* For this reason, we have chosen *A. grandis* as the epithet for the entire population. This genetic diversity appears partly responsible for extension of *A. grandis* to drier sites, resulting in a relatively large number of *A. grandis* h.t.'s in this area.

In general, the *Abies grandis* series indicates areas in central Idaho that experience some of the greatest moderating effects of the Pacific maritime influence. In Idaho, this influence is best reflected in the moist *Thuja* and *Tsuga* forests to the north of our study area. Undergrowth species common to these forests extend southward in the *Abies grandis* series and approach their environmental limits here.

The *Abies grandis* series lies between the drier *Pseudotsuga* series and the cooler *Abies lasiocarpa* series. Where *A. grandis* and *A. lasiocarpa* overlap, series designations are based on competitive potential. Stands where *A. grandis* is more successful than *A. lasiocarpa* are placed in the *A. grandis* series and vice versa. Thus, either species may appear as a minor climax component of the opposing series.

Vegetation. — This series has the most diverse floristics in central Idaho. *Pinus ponderosa, P. contorta, Pseudotsuga, Picea,* and *Larix occidentalis* are all seral species in at least part of this series. *Pinus ponderosa* and *Pseudotsuga* are the most prevalent. Climax undergrowths may resemble some of those in the *Pseudotsuga* series as well as the *Abies lasiocarpa* series. Seral stands can be quite diverse because of the large number of species capable of growing on these sites.

Soil. — Soils vary from clay loams to sandy loams and are mostly loams (appendix D). The parent materials are mostly granitic or basalt. Soil pH varies from 5.0 to 6.9. In general, soil conditions appear similar throughout the *Abies grandis* series, although soil-habitat type relationships may occur locally.

Fire. — Most vegetation in this series reflects considerable alteration by fire. The drier h.t.'s are often dominated by large *Pinus ponderosa* and *Pseudotsuga*, with undergrowths having high coverages of *Calamagrostis rubescens.* Obviously, fire has maintained these conditions because the frequent reinvasions of *Abies grandis* easily suppress regeneration of *Pinus* and *Pseudotsuga* as well as the growth of *Calamagrostis.* Even on more moist h.t.'s, the *Pinus* and *Pseudotsuga* often dominate an understory of *Abies grandis* and the undergrowth contains numerous seral species.

Productivity/Management. — This series provides the most productive timberlands and greatest silvicultural diversity in central Idaho. *Pinus ponderosa* and *Pseudotsuga* grow exceptionally well here and *Picea, Pinus contorta,* and even *Larix occidentalis* will grow on certain h.t.'s. On some of the drier sites in this series, growth rates of the *Abies* may equal or even surpass that of the seral species. Relative acreages of this series are quite small in our area, increasing further the timber value of these sites.

Frederick and Partridge (1977) studied the occurrence of decay in *Abies grandis* and its relationship to certain undergrowth species. They found a low incidence of decay on the drier sites that support high coverages of *Calamagrostis rubescens* and *Symphoricarpos albus.* Much of this condition would occur in the *ABGR/SPBE* and *ABGR/CARU* h.t.'s. We also noted remarkably few sporophores of *Echinodontium tinctorium* in these two h.t.'s.

In 1972, insect damage to the needles and new growth of *Abies, Picea,* and *Pseudotsuga* were noted throughout this series. Most of this damage was presumedly caused by western spruce budworm *(Choristoneura fumiferana)* and appeared concentrated geographically rather than by h.t. Infestation apparently increased northward and became notably severe around McCall, Idaho.

ABIES GRANDIS/CALAMAGROSTIS RUBESCENS H.T. *(ABGR/CARU;* GRAND FIR/PINEGRASS)

Distribution. — *ABGR/CARU* occurs as a minor h.t. in the Wallowa-Seven Devils section and western edge of the Southern Batholith section. Here it is found on gentle slopes and convex ridges at 5,200 to 6,100 feet (1 590 to 1 860 m). Usually it borders other *Abies grandis* h.t.'s, but occasionally it merges with *PSME/CARU.*

Figure 19. — Abies grandis/Calamagrostis rubescens h.t. on a gentle, southeast exposure just west of McCall, Idaho (5,250 feet [1 600 m] elevation). Abies grandis *and some* Pseudotsuga menziesii *are replacing an old growth stand of* Pinus ponderosa. Calamagrostis rubescens *and* Carex geyeri *codominate the undergrowth. Forbs and shrubs are very sparse throughout the stand.*

Vegetation. — *Pseudotsuga, Pinus contorta,* and *P. ponderosa* are the major seral trees. Shrubs are very sparse but small amounts of *Spiraea, Salix,* and *Amelanchier* are often present. *Calamagrostis rubescens* and *Carex geyeri* codominate the undergrowth (fig. 19). Forbs are sparse but usually include *Arnica* and *Osmorhiza.*

Soil. — Soil parent materials include basalt, granitics, and mixtures of granitics and rhyolite (appendix D). The textures vary from clay loam to sandy loam. Soil pH ranges from 5.7 to 6.3 and averages 6.1. Areas of bare rock or bare soil seldom exceed 2 percent. Litter depths on a site can average at least 5 cm.

Productivity/Management. — Timber productivity is moderate to high (appendix E-2). *Pseudotsuga, Pinus ponderosa,* and, on some sites, *P. contorta* all grow well here. However, the *Calamagrostis* sod may need scarification or other treatment to obtain prompt regeneration. *Abies grandis* seldom contains much heartrot in this h.t. and may be at least as productive as the seral trees.

Livestock frequent these sites due to the gentle terrain but find only moderate amounts of forage here. In some areas these sites may provide important forage and cover for deer and elk.

Other studies. — In eastern Oregon, Hall (1973) describes a "mixed conifer-pinegrass" community, part of which is similar to our *ABGR/CARU* h.t. He has also developed additional management implications for timber production and grazing on these sites.

ABIES GRANDIS/SPIRAEA BETULIFOLIA H.T. (*ABGR/SPBE;* GRAND FIR/WHITE SPIRAEA)

Distribution. — *ABGR/SPBE* occurs mostly in the Wallowa-Seven Devils and Southern Batholith sections. It is found from gentle benches to upper slopes that face south to west. It represents a warm, dry extreme of the *Abies grandis* series and occurs from 4,300 to 6,400 feet (1 310 to 1 950 m) in elevation.

Vegetation. — *Pinus ponderosa* and *Pseudotsuga* are the major seral trees. *Pinus contorta* and *Picea* are usually absent. In old-growth stands, *Spiraea* usually forms a light cover in the undergrowth and *Thalictrum occidentale* often becomes the dominant forb (fig. 20). On some sites, *Symphoricarpos albus* will dominate instead of *Spiraea.* Under dense tree canopies, *Arnica cordifolia* and *Chimaphila umbellata* may dominate the undergrowth.

In seral condition, *Calamagrostis rubescens* can form a dense sod beneath open stands of *Pinus ponderosa* and *Pseudotsuga.* Then, only the layer of *Spiraea* will distinguish *ABGR/SPBE* from *ABGR/CARU.*

In a few areas near Banks, Idaho, *Lathyrus nevadensis* var. *cusickii* apparently replaces *Spiraea.* This anomaly appears most similar to *ABGR/SPBE* and is included herein.

Soil. — Soil parent materials are mostly basalt and occasionally granitics (appendix D). Textures vary from clay loam to sandy loam. The pH ranges from 5.5 to 6.4 and averages 6.0. Areas of bare rock and soil are less than 1 percent on most sites. Average litter depths per site can reach at least 6 cm.

Productivity/Management. — Timber productivity is high to very high (appendix E-2). *Pinus ponderosa* and *Pseudotsuga* should regenerate well in small clearings. *Abies grandis* can regenerate in partial shade and, in some areas, can grow at least as fast as the pine when given adequate sunlight. If a *Calamagrostis* sod is present, site preparation will be needed to achieve adequate stocking.

Livestock use the gentle terrain of these sites but find little forage beneath the trees.

Some of these sites may provide important food and cover for deer, elk, and black bear and important nesting areas for ruffed grouse.

Other studies. — No one has described *ABGR/SPBE* from other areas but some of Hall's (1973) "mixed conifer-pinegrass" communities in the Blue Mountains probably relate to this h.t.

ABIES GRANDIS/VACCINIUM GLOBULARE H.T. (*ABGR/VAGL;* GRAND FIR/BLUE HUCKLEBERRY)

Distribution. — *ABGR/VAGL* occurs mainly in the Wallowa-Seven Devils and Southern Batholith sections. It is usually found from 4,500 to 6,500 feet (1 370 to 1 980 m) in elevation, on moist slopes and benches that face north to east. It represents cool extremes of the *Abies grandis* series and often merges with *Abies lasiocarpa* h.t.'s

Vegetation. — Some *Pinus ponderosa* and sometimes *Larix occidentalis* may be present, but *Pinus contorta, Pseudotsuga,* and *Picea* are the predominant seral trees. Small amounts of *Abies lasiocarpa* are often a minor climax component. *Vaccinium globulare* usually dominates an undergrowth containing small amounts of numerous forbs. *Lonicera utahensis* is the most frequent associate of the *Vaccinium.*

Soil. — Soil parent materials are either basalt or granitics (appendix D). Textures vary from loam to sandy loam and are mostly loam. The pH ranges from 5.2 to 6.8 but averages 5.9. Areas of bare rock and soil are negligible. Average litter depths on a site can reach at least 7 cm.

Figure 20. — Abies grandis/Spiraea betulifolia *h.t. on a northwest exposure east of Cascade, Idaho (6,400 feet [1 950 m] elevation). A near-climax stand of* Abies grandis *dominates an undergrowth composed mainly of* Spiraea betulifolia *and* Thalictrum occidentale.

Productivity/Management. — Timber productivity is generally high (appendix E-2). *Picea* and *Pseudotsuga* have the highest site indexes (appendix E-2). If present, *Pinus contorta* should regenerate well in small clearings. Areas with partial shade will favor *Pseudotsuga, Picea,* and *Abies.*

Seral stands may provide important forage and cover for elk and occasionally whitetail deer. The berry crops of *Vaccinium* are important for black bear, ruffed grouse, and to a lesser extent, blue grouse.

Other studies. — Hall (1973) described a "white fir - big huckleberry" community type in eastern Oregon. Part of this community is similar to our *ABGR/VAGL* h.t.

ABIES GRANDIS/XEROPHYLLUM TENAX H.T. (*ABGR/XETE;* GRAND FIR/BEARGRASS)

Distribution. — This incidental h.t. occurs mainly in eastern portions of the Nezperce National Forest and in adjacent Montana. Small amounts also occur southeast of McCall, Idaho. Like *ABGR/VAGL,* it too represents cool extremes of the *Abies grandis* series and often merges with *Abies lasiocarpa.*

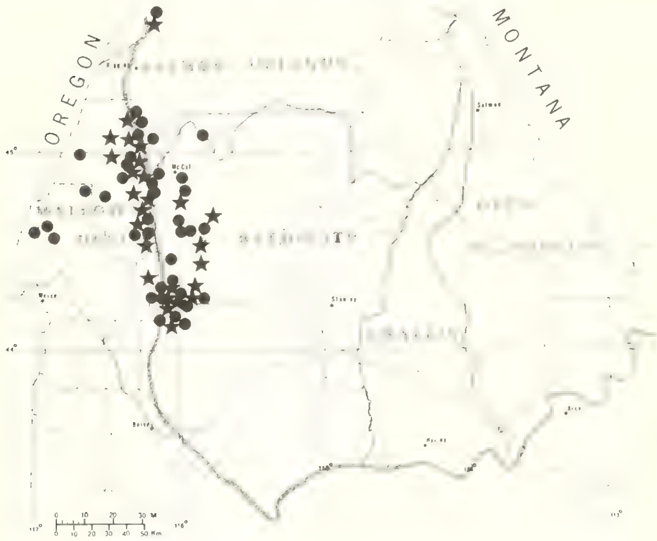
Vegetation. — In seral condition, *Pinus contorta* followed by *Pseudotsuga* are the major successional species. Occasionally, *Larix occidentalis, Pinus ponderosa,* or *Picea* are also present. In older stands, small amounts of *Abies lasiocarpa* often grow with *A. grandis.* In both cases *Xerophyllum tenax* and *Vaccinium globulare* usually codominate the undergrowth.

Productivity/Management. — Only limited data on timber productivity are available, but yield capability is probably moderate to high. On most sites *Pinus contorta* should regenerate well in clearings. Openings with partial shade will favor *Pseudotsuga* and *Abies.*

Early successional stages offer limited forage for deer and elk, and the sites are seldom accessible for winter use. The *Vaccinium* berries are sought by black bear, grouse, and humans.

Other studies. — Pfister and others (1977) describe *ABGR/XETE* in Montana, and Steele and others (1976, unpubl. ref.) describe it on the Nezperce National Forest.

ABIES GRANDIS/ACER GLABRUM H.T. *(ABGR/ACGL;* GRAND FIR/MOUNTAIN MAPLE)



•*Acer glabrum* phase
(ACGL; mountain maple)
★ *Physocarpus malvaceus* phase
(PHMA; ninebark)

Distribution. — *ABGR/ACGL* occurs mainly in the Wallowa-Seven Devils and Southern Batholith sections. This h.t. usually ranges from 3,800 to 6,400 feet (1 160 to 1 950 m) in elevation and occupies the mid- to lower slopes that face north to east. It also extends down drainages and interfingers with the warmer and drier *PSME/PHMA* and *ABGR/SPBE* h.t.'s

Vegetation. — *Pinus ponderosa* and *Pseudotsuga* are vigorous seral dominants. Lesser amounts of *Picea, Larix,* and *Abies lasiocarpa* sporadically occur here. Shrub layers vary between phases noted below. When tree canopies become dense and the shrubs become depauperate, the more shade-tolerant forbs *Adenocaulon* and *Disporum* help indicate this h.t. Where fire or logging has removed the overstory, a dense layer of tall shrubs persists for several decades.

Physocarpus malvaceus (PHMA) phase. — The *PHMA* phase represents a warm, dry variant of the h.t. and often borders *PSME/PHMA. Physocarpus* is usually the dominant shrub although coverages may be low in dense stands. A layer of *Symphoricarpos, Spiraea,* or occasionally *Pachistima* may be present. A layer of *Calamagrostis rubescens* is also common in this phase.

Acer glabrum (ACGL) phase. — This phase is found on the more moist aspects of areas occupied by the *PHMA* phase. *Acer glabrum* typically dominates the shrub layer in old-growth stands (fig. 21). Shrubs common to the *PHMA* phase may also occur here and *Sorbus scopulina* occurs more frequently. *Calamagrostis rubescens* seldom develops high coverages.

Soil. — Soil parent materials are mainly basalt, granitics, and occasionally quartz diorite (appendix D). Textures range from clay loam to sandy loam and a few are gravelly. The pH ranges from 5.6 to 6.7 and averages 6.1. Areas of bare rock or bare soil seldom exceed 5 percent. Litter depths can average 10 cm on a site.

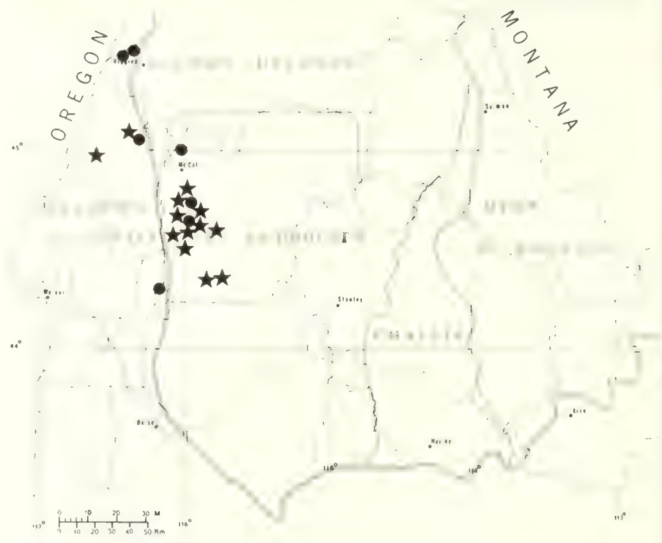
Productivity/Management. — Timber productivities are generally high to very high (appendix E-2). Both *Pseudotsuga* and *Pinus ponderosa* should regenerate well wherever they escape competition of the shrubs and tree canopy. Complete removal of overstories may allow suppressed shrubs to develop a tall, dense layer that will persist for several decades.

Livestock find little forage in old-growth stands but may use early successional stages.

ABGR/ACGL provides important forage and cover for elk, mule deer, and, in some areas, whitetail deer. Seral conditions, especially, produce an abundance of browse and the berry crops of a few species are important to black bear. When a tree canopy is present, these sites become important habitat for ruffed grouse.

Other studies. — No other studies have described this h.t.

ABIES GRANDIS/LINNAEA BOREALIS H.T. *(ABGR/LIBO;* GRAND FIR/TWINFLOWER)



•*Linnaea borealis* phase
(LIBO; twinflower)
★ *Vaccinium globulare* phase
(VAGL; blue huckleberry)

Distribution. — *ABGR/LIBO* occurs in the Wallowa-Seven Devils, Salmon Uplands and Southern Batholith sections. This h.t. is usually found at lower elevations of the *Abies grandis* series and ranges from 3,400 to 5,600 feet (1 040 to 1 710 m). It occupies relatively

Figure 21. — Abies grandis/Acer glabrum h.t., Acer glabrum phase on a concave, northerly exposure north of Crouch, Idaho (4,100 feet [1 250 m] elevation). An old-growth stand of Abies grandis dominates a layer of shrubs composed mainly of Acer glabrum, Physocarpus malvaceus, and Sorbus scopulina.

gentle slopes and benches that are protected from extreme sun and wind.

Vegetation. — Plant composition varies between phases, as noted below. In all cases, however, *Linnaea borealis* tends to form a fairly extensive mat in old-growth stands.

Vaccinium globulare (VAGL) phase. — This phase reflects some of the cooler conditions within the h.t. Small amounts of *Abies lasiocarpa* may be present and *Picea* is a common seral tree. Lesser amounts of *Pseudotsuga, Pinus contorta,* and *P. ponderosa* may be present. *Vaccinium globulare* usually dominates the undergrowth.

Xerophyllum tenax (XETE) phase. — This phase occurs mainly in the Clearwater drainage and in Montana. It is a very minor phase in our study area. The undergrowth resembles that of the *VAGL* phase except *Xerophyllum tenax* is an additional component. Seral overstories include less *Picea* than the *VAGL* phase and more *Pinus ponderosa* and *Pseudotsuga.*

Linnaea borealis (LIBO) phase. — The *LIBO* phase is most common in mountains nearest the Oregon border. *Pinus ponderosa* and *Pseudotsuga* are the major seral dominants. Shrub layers are normally sparse in older stands (fig. 22), although *Amelanchier* and *Rosa gymnocarpa* are usually present.

Soil. — Soil parent materials are mainly basalt, andesite, and granitics (appendix D). Textures are usually loamy and sometimes gravelly. The pH ranges from 5.4 to 6.9 and averages 6.0. Areas of bare soil and bare rock are usually negligible. Litter depths can reach 9 cm.

Productivity/Management. — Timber productivity data is scarce, but yield capabilities appear to range from moderate to very high. The *VAGL* phase apparently is less productive than the *LIBO* phase. *Pinus ponderosa* should regenerate well wherever openings eliminate competition from larger trees. Smaller openings will favor *Pseudotsuga* and *Abies grandis* (and *Picea* in the *VAGL* phase).

*Figure 22. — *Abies grandis/Linnaea borealis *h.t.,* Linnaea borealis *phase on a gentle northerly exposure northwest of Riggins, Idaho (4,500 feet [1 370 m] elevation). A pure stand of* Abies grandis *dominates a low undergrowth composed mainly of* Linnaea borealis, Trifolium latifolium, *and* Viola orbiculata. *Numerous other forbs and a few shrubs are present in small amounts.*

The gentle terrain may attract livestock to these sites, but timbered stands seldom provide much forage.

Early successional stages may produce good browse for deer and elk, but the sites are seldom accessible in winter. Older stands may be important nesting sites for ruffed grouse. In the *VAGL* phase, the *Vaccinium* fruits are important to black bear, grouse, and humans.

Other studies. — Pfister and others (1977) describe *ABGR/LIBO* in Montana. In eastern Oregon, Hall (1973) mentions a "white fir-twinflower-forb" community that probably occupies this h.t.

ABIES GRANDIS/VACCINIUM CAESPITOSUM H.T. (*ABGR/VACA*; GRAND FIR/DWARF HUCKLEBERRY)

Figure 23. — Abies grandis/Vaccinium caespitosum *h.t. on a broad alluvial terrace northeast of Donnelly, Idaho (5,450 feet [1 660 m] elevation).* Abies grandis *is slowly replacing a stand of* Pinus contorta. *The undergrowth consists mainly of* Vaccinium caespitosum, Calamagrostis rubescens, *and* Fragaria virginiana.

Distribution. — This minor h.t., mainly found in the Southern Batholith section, is restricted to gentle alluvial terraces and glacial outwash, from 4,600 to 5,500 feet (1 400 to 1 680 m). Although they occur at mid-elevations of the *Abies grandis* zone, these sites lie within frost pockets and have relatively severe environments. Adjacent uplands are often the warmer *ABGR/SPBE* or *PSME/SPBE* h.t.

Vegetation. — *Pinus contorta* persists as a seral dominant on most of these sites. Small amounts of *Populus tremuloides* are also common. *Pseudotsuga, Picea,* and occasionally *Larix* gradually replace the pine and aspen. *Abies grandis* and small amounts of *A. lasiocarpa* usually appear with the *Pseudotsuga* and *Picea* (fig. 23). *Vaccinium caespitosum* normally dominates the undergrowth. Many forbs are often present in small amounts. *Fragaria virginiana* and *Calamagrostis rubescens* are the most common components of the forb layer.

Soil. — The soils are depositional, largely of granitic origin, and are mostly clay loams to sandy loams. A few are gravelly. The pH ranges from 5.0 to 5.6. Areas of bare rock and bare soil are negligible. Litter depths on a site can average at least 3 cm.

Productivity/Management. — Timber productivity is moderate to high (appendix E-2). *Pinus contorta* should regenerate in any clearing that receives ample sunlight. Although *Picea* and *Pseudotsuga* may establish naturally beneath the pine, plantings may be damaged by untimely frosts.

The gentle terrain may attract livestock, but the animals find only moderate forage here. Elk and whitetail deer use the cover on these sites, but find much of their browse on adjacent h.t.'s

Other studies. — No one else has described this h.t.

ABIES GRANDIS/COPTIS OCCIDENTALIS H.T. (*ABGR/COOC*; GRAND FIR/WESTERN GOLDTHREAD)

Distribution. — A few isolated sites of this incidental h.t. occur on the Payette and Salmon National Forests in central Idaho. The main occurrence is on the Nezperce National Forest between the South Fork of the Clearwater and Salmon Rivers.

Vegetation. — *Pinus contorta, P. ponderosa,* or *Larix occidentalis* may dominate early successional stages. *Pseudotsuga* or *Picea* may dominate the later stages. *Coptis occidentalis* is common throughout the undergrowth and often dominates the forb layer. In some areas, *Xerophyllum* and *Vaccinium globulare* form a dominant layer.

Productivity/Management. — Timber productivity should be nearly as high as that of the *ABGR/CLUN* h.t. and silvicultural treatments should be similar. When *Pinus ponderosa* or *P. contorta* are naturally present plantations of the appropriate pine have been very successful.

Livestock, deer, and elk use these sites only lightly.

Other studies. — *ABGR/COOC* is described on the Nezperce National Forest (Steele and others 1976, unpubl. ref.) but not elsewhere.

ABIES GRANDIS/CLINTONIA UNIFLORA H.T. (*ABGR/CLUN;* GRAND FIR/QUEENCUP BEADLILY)

Distribution. — *ABGR/CLUN* occurs mainly in the Wallowa-Seven Devils and Southern Batholith sections. It represents a warm, moist extreme of the *Abies grandis* series and usually occurs at mid-elevations of the forested zone. It ranges from 3,900 to 5,900 feet (1 190 to 1 800 m) in elevation and normally occupies moist, well-drained slopes, benches, and stream terraces that are protected from extreme sun and wind.

Vegetation. — *Pinus ponderosa, Larix occidentalis,* and occasionally *Pinus contorta* are the primary invaders of severely disturbed sites. *Pseudotsuga* and *Picea* usually act as secondary seral dominants. *Clintonia uniflora* occurs throughout the stand and accompanies a mixture of moist site forbs. In some areas *Vaccinium globulare* or *Acer glabrum* dominate the undergrowth. Throughout the h.t., tall shrubs often invade when the tree canopy is removed.

Soils. — Soil parent materials are usually basalt or granitics (appendix D). Textures range from loam to sandy loam. Soil pH varies from 5.5 to 6.3 and averages 5.9. Areas of bare soil and bare rock are normally less than 1 percent. Average litter depth on a site can reach at least 5 cm.

Productivity/Management. — Timber productivity is usually high (appendix E-2), with a wide choice of silvicultural options. If present, *Pinus ponderosa, P. contorta,* and *Larix occidentalis* should regenerate best in openings that eliminate competition from older trees. Smaller openings with partial shade will favor *Pseudotsuga, Picea,* and *Abies grandis.* Both artificial and natural regeneration should prove successful on properly prepared sites. Young *Pinus ponderosa* grow rapidly but sampling only the near-climax conditions precluded a meaningful site index for this species. Daubenmire (1961) found that *P. ponderosa* grew most rapidly on these sites for the first 50-60 years. After age 60, the pine showed higher productivity on *PSME/PHMA* and *PIPO/PHMA* h.t.'s.

Livestock find very little forage on timbered sites. Early succession following major disturbances may produce some forage.

These sites can provide important browse and cover for elk and whitetail deer. Early seral stages often produce high-quality browse, but snow depths may prevent winter use. *ABGR/CLUN* provides good ruffed grouse habitat and, when *Vaccinium globulare* is present, food for black bear.

Other studies. — Pfister and others (1977) describe *ABGR/CLUN* in Montana and recognize three phases. Most of R. and J. Daubenmire's (1968) *Abies grandis/Pachistima myrsinites* h.t. in northern Idaho and eastern Washington also corresponds to *ABGR/CLUN.* We used *Clintonia uniflora* instead of *Pachistima myrsinites* to name this h.t. because *Pachistima* is usually absent and members of the "*Pachistima* union" meet their southern limits independently in our area.

Abies lasiocarpa Series

Distribution. — The *Abies lasiocarpa* series occurs at upper elevations throughout most of central Idaho. In the western portion, lower limits of this series merge with *Abies grandis.* Here, moisture is adequate for both species. This ecotone probably relates best to temperature as does the *A. lasiocarpa* ecotone with

Thuja and *Tsuga* (Daubenmire 1956); however, in most of central Idaho, lower limits of *A. lasiocarpa* merge with the *Pseudotsuga* zone and both moisture and temperature appear to be controlling factors.

Near its upper limits, the *Abies lasiocarpa* series borders various alpine communities or grassy balds dominated by *Festuca idahoensis*. *Pinus albicaulis* becomes increasingly prevalent toward the upper limits of this series and may form pure stands on the most severe exposures.

Vegetation. — At lower elevations of this series, *Pseudotsuga* often acts as the major seral species. However, *Pinus contorta* fills this role throughout most subalpine forests in central Idaho. Its successional role varies from a rapidly replaced species to one that reproduces and persists as a dominant for many years. Some sites with high water tables support dominant stands of long-lived, but seral, *Picea engelmannii*.

Undergrowth is variable and may include dense, tall-shrub layers, lush, moist-site forb layers, depauperate layers of dry-site forbs and open, grassy parks. Because of short growing seasons, disturbed undergrowths recover very slowly. The limited number of species adapted to low temperatures allows even less opportunity for revegetation. Frequent disturbance such as grazing can easily destroy the plant cover and expose the soil to erosion. Plants that indicate disturbance are sometimes scarce in this series, which confounds the difficulty of identifying areas that need attention. A few species, however, appear to indicate disturbance in many areas. *Polygonum phytolaccaefolium* and, on moist sites, *Veratrum viride* can increase markedly with grazing. Grazing abuse may also produce high coverages of *Spraguea umbellata*. On some sites, high coverages of *Penstemon attenuatus* and *Potentilla glandulosa* reflect past disturbance, mainly grazing, and *Epilobium angustifolium* often attains high coverages on moist sites following fire or logging.

Soils. — Most soils in this series ranged from gravelly loam to sandy loam. Habitat types showed little overall correlation with soil parent materials that varied from granitics and volcanics to sedimentaries. A few exceptions are noted under the appropriate h.t.

Fire. — Alteration by fire remains evident for many decades and even centuries. Stands of fire-induced *Pinus contorta* dominate large areas, and the reduced seed sources of other conifers delay their replacement. Repeated wildfire further depletes seed sources of other conifers in the area. This leads to even more uniform stands of *P. contorta* which, when mature, create epidemic potentials for insects and disease. Harvesting *P. contorta* interrupts the cycle by removing fuels of future fires and the nurseries of insects and disease. Well-regulated harvesting can also create stands of varied ages, which further disrupts stand uniformity and reduces epidemic potentials.

In many areas, undergrowths in this series reflect only moderate alteration by fire. However, at lower elevations, *Calamagrostis rubescens* often persists under near-climax conditions and responds to burning as outlined under the *Pseudotsuga* series. *Shepherdia canadensis* may also increase following burning, particularly on certain sites in the Challis and Open Northern Rockies sections. Here it may dominate the undergrowth until *Abies lasiocarpa* replaces the open canopy of *Pinus contorta*.

Productivity/Management. — Lower-elevation sites within the *Abies lasiocarpa* series have the highest timber potentials. Here *Pseudotsuga* is often the most productive species, but regeneration is sometimes difficult to obtain. *Pinus contorta* responds better to silvicultural treatments and is fairly productive throughout much of this series. *Picea* grows well on many sites but is susceptible to windthrow in partially cut stands, especially on those sites with high water tables. These sites with excess moisture almost always require special consideration during timber harvest and stand regeneration.

Upper-elevation sites within this series have low timber potential and are best suited for recreation, wildlife, and snowpack management.

ABIES LASIOCARPA/CALTHA BIFLORA H.T. (*ABLA/CABI*; SUBALPINE FIR/MARSH MARIGOLD)

Distribution. — This minor type occurs mainly in the Southern Batholith section, but extends north to at least the Salmon-Clearwater divide. It ranges from 6,200 to 7,800 feet (1 890 to 2 380 m) in elevation and occurs mostly on wet, gentle terrain in the middle to upper portions of the subalpine zone. This h.t. denotes some of the wettest sites in this series.

Vegetation. — Long-lived *Picea engelmannii* codominates these sites with *Abies lasiocarpa*. The

Figure 24. — Abies lasiocarpa/Caltha biflora *h.t. on a wet bench near Bear Valley Creek northwest of Stanley, Idaho (7,300 feet [2 230 m] elevation).* Picea engelmannii *and scattered* Pinus contorta *dominate the site. Young* Abies lasiocarpa *occur beneath the* Picea. Caltha biflora *and* Dodecatheon jeffreyi *are the dominant forbs. The conspicuous graminoids are* Calamagrostis canadensis *and* Carex scopulorum.

Picea acts as a persistent seral species and may attain large diameters. The *Abies* seedlings gradually outnumber those of *Picea* and will achieve dominance at climax. In the undergrowth, numerous wet-site forbs dominate (fig. 24) and may obscure the presence of *Caltha*. With increasing shade, many of the forbs decrease and *Caltha* becomes more evident. *Lonicera involucrata, Pedicularis bracteosa,* and *Dodecatheon jeffreyi* also occur here regularly. Shrubs typical of drier sites, such as *Vaccinium scoparium,* often grow on hummocks or at the base of large trees. A notable moss layer also occurs on these sites; dominant species normally include *Aulacomnium palustre, Bryum weigelii,* and *Campylium stellatum* (Steele 1974).

Soil. — Substrates in this h.t. often consist of a thick layer (20 + cm) of organic material overlying loamy to sandy loam soils (appendix D-1). Soil parent materials are primarily granitic. Soil pH ranges from 4.9 to 6.2 and averages 5.2. Areas of bare soil and bare rock are negligible.

Productivity/Management. — Timber productivity is moderate to high (appendix E-2). *Picea engelmannii* grows well here, but regeneration often is limited to the raised microsites within the stands. If the large trees are removed, water tables are likely to rise and seriously impede tree regeneration. Most disturbances can degrade these sites to a bog-like condition. Livestock and machinery can easily churn the wet substrate and destroy considerable undergrowth. Acreages of this h.t. are usually small locally but require recognition when considering access and use of adjacent h.t.'s. Hazards to soil and water resources may result from almost any manipulation of these sites.

This h.t. is very important to elk in summer and fall. The many lush forbs and proximity to water create important feeding areas, and the wet depressions provide excellent elk wallows. Mule deer also find important forage here in summer and fall. Black bear, too, forage and wallow on these sites and Franklin's grouse seek food and cover here.

Other studies. — *ABLA/CABI*, not described elsewhere, is central Idaho's counterpart of the *Abies lasiocarpa/Caltha leptosepala* h.t. found in the Uinta Mountains of Utah (Henderson and others 1977, unpubl. ref.).

ABIES LASIOCARPA/CALAMAGROSTIS CANADENSIS H.T. *(ABLA/CACA;* SUBALPINE FIR/ BLUEJOINT)

•*Ligusticum canbyi* phase (*LICA;* Canby's ligusticum)

★ *Ledum glandulosum* phase (*LEGL;* Labrador tea)

✱*Vaccinium caespitosum* phase (*VACA;* dwarf huckleberry)

◉*Calamagrostis canadensis* phase (*CACA;* bluejoint)

Distribution. — *ABLA/CACA* is widespread in central Idaho but is most prevalent in the Southern Batholith section. It usually appears at middle to upper elevations of the subalpine zone where it ranges from 6,400 to 9,000 feet (1 950 to 2 740 m). It also extends to as low as 4,600 feet (1 400 m) in frost pockets and along cold-air drainages. It usually occupies moist toe-slopes, terraces, and bottom lands associated with streams and lakes.

Vegetation. — *Pinus contorta* and *Picea* are the major seral conifers. Usually *Calamagrostis canadensis* is conspicuous in the undergrowth but codominates with different species, depending on the phases noted below. Shrubs characteristic of drier sites may grow on hummocks or at the base of trees.

Ledum glandulosum (LEGL) phase. — This phase occurs sporadically throughout the range of *ABLA/CACA*. It represents the colder or higher extremes (4,700 to 9,000 feet [1 430 to 2 740 m]) of the h.t. *Ledum glandulosum* forms a dominant undergrowth (fig. 25) and *Gaultheria humifusa* occurs here more frequently than in other h.t.'s or phases. At the upper elevations of this phase *Phyllodoce empetriformis* may accompany the *Ledum*, and *Calamagrostis canadensis* becomes increasingly scarce.

Vaccinium caespitosum (VACA) phase. — This phase occurs mainly in the Southern Batholith section of Idaho and in Montana (Pfister and others 1977). Although it often occurs at lower elevations (4,600 to 7,200 feet [1 400 to 2 200 m]) of the h.t., it usually represents a frost-pocket condition. Consequently its best development is in gentle valleys that impound cold air. These sites usually contain coarse alluvium, especially glacial outwash. This phase often merges with *ABLA/VACA* on drier sites. Usually *Pinus contorta* is a persistent seral dominant, with lesser amounts of *Picea* and *Abies lasiocarpa* (fig. 26). *Vaccinium caespitosum* is common throughout the stand. It is often accompanied by *Ligusticum tenuifolium* and *Lonicera caerulea*, which are somewhat restricted to this phase.

Ligusticum canbyi (LICA) phase. — The *LICA* phase extends slightly north and south of its center in the Salmon Uplands section. This phase seems to reflect the more moderate environments of the stronger maritime influence in this area. Usually the *LICA* phase occupies stream terraces and wet benchlands at lower to mid-elevations (5,400 to 7,400 feet [1 650 to 2 260 m]) of the h.t. It has a rich assortment of forbs, which suggests higher productivity potentials (fig. 27). *Ligusticum canbyi* or *Trautvetteria caroliniensis* are often the dominant forbs and *Pedicularis bracteosa* is regularly present. *Picea* is the major seral dominant while *Pinus contorta* is less abundant than in the other phases.

Calamagrostis canadensis (CACA) phase. — This phase occurs mainly south and east of the *LICA* phase and is the typical phase throughout much of the *ABLA/CACA* distribution. It occurs at the lower to mid-elevations (4,700 to 7,500 feet [1 430 to 2 290 m]) of the h.t. *Calamagrostis canadensis* often creates a sward appearance and obscures the forb layer (fig. 28). Other features of this phase correspond to the general description of the *ABLA/CACA* h.t.

Soil. — Soil parent materials are mainly granitic but also include quartzite, quartz monzonite, and trachyte (appendix D-1). The textures are mostly loams but range from loam to loamy sand. A few are gravelly. Soil pH ranges from 4.6 to 6.4 and averages 5.1. Areas of bare soil or rock are negligible on most sites. Average litter depths on a site can reach 13 cm.

Productivity/Management. — Timber productivity varies from low to high, depending on the phase involved (appendix E-2). The *LICA* phase has the highest potential. *Pinus contorta* may be the easiest conifer to regenerate but in the *LICA* and *CACA* phases, *Picea* should yield more timber. These sites can be prepared for planting in late summer after they have dried enough to support machinery. Plantings of *Picea* in contour trenches have

Figure 25. — Abies lasiocarpa/Calamagrostis canadensis *h.t.*, Ledum glandulosum *phase on a broad stream terrace south of Dixie, Idaho (5,250 feet [1 600 m] elevation.* Abies lasiocarpa *and* Picea engelmannii *are replacing a stand of* Pinus contorta. Ledum glandulosum *dominates the undergrowth.*

Figure 26. — Abies lasiocarpa/Calamagrostis canadensis *h.t.*, Vaccinium caespitosum *phase on an alluvial flat near Alturas Lake southeast of Stanley, Idaho (7,050 feet [2 150 m] elevation).* Abies lasiocarpa *and* Picea engelmannii *are slowly increasing in a multiage stand of* Pinus contorta. Vaccinium caespitosum *and* Calamagrostis canadensis *codominate the undergrowth.*

Figure 27. — Abies lasiocarpa/Calamagrostis canadensis *h.t.,* Ligusticum canbyi *phase on a wet bench near Cloochman Creek north of McCall, Idaho (6,200 feet [1 890 m] elevation).* Abies lasiocarpa *and* Picea engelmannii *codominate the site.* Calamagrostis canadensis *and a rich mixture of forbs forms the undergrowth. The most conspicuous forbs are* Ligusticum canbyi, Aconitum columbianum, *and* Dodecatheon jeffreyi.

Figure 28. — Abies lasiocarpa/Calamagrostis canadensis *h.t.,* Calamagrostis canadensis *phase on an alluvial flat above Alturas Lake southeast of Stanley, Idaho (7,100 feet [2 160 m] elevation).* Abies lasiocarpa *and* Picea engelmannii *are invading a multiage stand of* Pinus contorta. Calamagrostis canadensis *dominates the undergrowth.*

been successful where grazing was restricted. *Picea* may also regenerate naturally with adequate site preparation but longer periods of grazing protection are needed. In all phases of this h.t., partial cutting leaves the remaining large trees especially prone to windthrow. Overstory removal permits water tables to rise and allows the *Calamagrostis* and *Carex* species to increase and outcompete conifer seedlings.

Livestock may find considerable forage here, and the adjacent streams attract many animals. But until late summer, the animals can easily churn the wet soil and destroy the plant cover as well as conifer seedlings. Depending on location, these sites may provide important food and cover for moose, elk, deer, black bear,and Franklin's grouse. The elk and bear can make wallows in the wet spots and seral stages can produce willows and abundant sedges. The *LICA* phase, especially, produces many lush forbs and whitetail deer are frequently found here.

Other studies. — *ABLA/CACA* also occurs in Montana (Pfister and others 1977), northwestern Wyoming (Cooper 1975), and the Unita Mountains of northeastern Utah (Henderson and others 1977, unpubl. ref.).

ABIES LASIOCARPA/STREPTOPUS AMPLEXIFOLIUS H.T. (*ABLA/STAM;* SUBALPINE FIR/ TWISTED STALK)

•*Ligusticum canbyi* phase (*LICA;* Canby's ligusticum)

★ *Streptopus amplexifolius* phase (*STAM;* twisted stalk)

Distribution. — *ABLA/STAM* is a minor h.t. that occupies very moist slopes and alluvial terraces in the middle to lower portions of the subalpine zone. It normally ranges from 4,500 to 8,000 feet (1 370 to 2 440 m) in elevation. As in *ABLA/CACA,* these sites seem influenced by higher water tables, but the two h.t.'s seldom border each other.

Vegetation. — *Picea* usually dominates the stand as a long-lived seral species. In openings, seral undergrowths normally appear as lush, tall-forb communities that usually include *Senecio triangularis.* Beneath closed canopies, undergrowths become more sparse; then either *Streptopus amplexifolius, Ligusticum canbyi,* or *Trautvetteria caroliniensis* prevails as the most shade-tolerant forb, depending on the phases noted below. Rivulets bordered by high coverages of *Saxifraga arguta* are common.

Ligusticum canbyi (LICA) phase. — The *LICA* phase appears mainly in the Salmon Uplands section. Usually, *Ligusticum canbyi* or *Trautvetteria caroliniensis,* or both, dominate the forb layer of mature stands. *Vaccinium globulare* is the most common shrub. Adjacent drier sites often support *Clintonia* or *Xerophyllum.*

Streptopus amplexifolius (STAM) phase. — This phase occurs mainly to the south and east of the *LICA* phase. *Streptopus* tends to become a conspicuous forb in old-growth stands and *Ribes lacustre* is the most common shrub.

Soil. — Soil parent materials are mainly granitics and basalt but also include quartzite, quartz monzonite, and rhyolite (appendix D-1). The textures range from loam to sandy loam and are mostly loam. A few are gravelly. Soil pH ranges from 4.7 to 6.1 and averages 5.4. Areas of bare soil or bare rock are usually less than 1 percent. Litter depths can reach at least 9 cm.

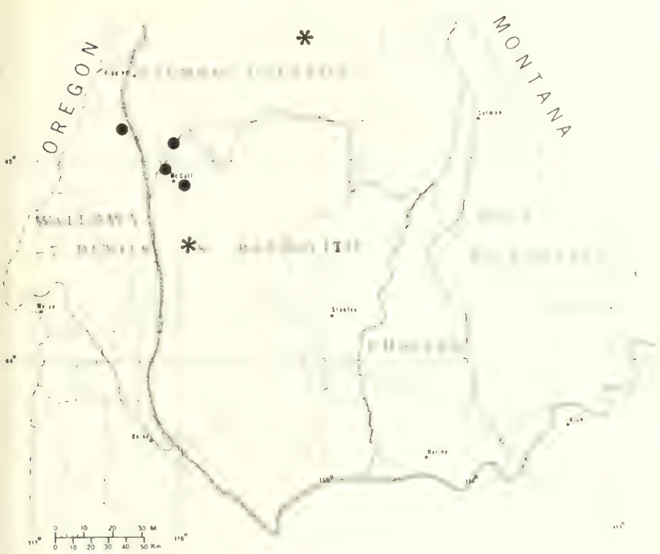
Productivity/Management. — Timber potential is moderate to high (appendix E-2). *Picea* is the most productive species, but high water tables hamper timber management.

Forage is often abundant in seral stands and the nearby streams also attract livestock. However, the animals can easily churn the wet soil with their hooves and destroy the plant cover and tree seedlings.

In certain areas this h.t. may provide important forage and cover for elk and the wet spots make good wallows. The food and cover on these sites may also be important to moose, mule deer, black bear, and Franklin's grouse.

Other studies. — *ABLA/STAM* also occurs in the Uinta Mountains of Utah (Henderson and others, 1977, unpubl. ref.) and in the Teton Mountains of Wyoming (Steele and others 1979, unpubl. ref.). In some respects *ABLA/STAM* is related to the *ABLA/CACA* h.t., *Galium triflorum* phase, and *ABLA/GATR* h.t. in Montana (Pfister and others 1977). *ABLA/STAM* appears to be transitional to those conditions in our Open Northern Rockies section but never has *Calamagrostis canadensis* well represented.

ABIES LASIOCARPA/CLINTONIA UNIFLORA H.T. (*ABLA/CLUN*; SUBALPINE FIR/QUEENCUP BEADLILY)



•*Clintonia uniflora* phase (*CLUN;* queencup beadlily)

**Menziesia ferruginea* phase (*MEFE;* menziesia)

Distribution. — *ABLA/CLUN* is a minor h.t. restricted mainly to the western portions of the Salmon Uplands section and the extreme northwestern corner of the Southern Batholith section. Here it ranges from 5,100 to 5,500 feet (1 550 to 1 680 m) in elevation and occupies moist slopes, benches, and stream terraces. It is found in lower portions of the *Abies lasiocarpa* zone and denotes some of the most moderate conditions for plant growth in this series. Its warm extreme usually borders the *Abies grandis* zone.

Vegetation. — *Pseudotsuga, Picea,* and *Pinus contorta* are the major seral species. This is one of the few subalpine h.t.'s in central Idaho that supports *Larix occidentalis.* Quite often the undergrowth is a variable mixture of shrubs and forbs, leaving *Clintonia* as the most dependable indicator of this h.t. Occasionally *Menziesia ferruginea* creates a dominant layer and denotes the *Menziesia* phase. In most of our area, *Vaccinium globulare* dominates the undergrowth but does not appear to warrant phasal status.

Menziesia ferruginea (MEFE) phase. — This incidental phase occurs mainly north of our area and represents a cooler segment of the h.t. Its upper limits often merge with *ABLA/MEFE,* and the layer of *Menziesia* is similar in both cases.

Clintonia uniflora (CLUN) phase. — This is the common phase in our area and fits the general description of the h.t.

Soil. — Soil parent materials are mainly granitics and the textures are loam to fine sandy loam (appendix D-1). The pH ranges from 5.3 to 5.8 and averages 5.5. Areas of bare rock and bare soil are negligible. Litter depths on a site can average at least 7 cm.

Productivity/Management. — Limited data suggest that timber potential is high. *Pinus contorta* and *Larix occidentalis* often regenerate easily and grow vigorously in clearings that receive adequate sunlight. *Pseudotsuga* and *Picea* may also regenerate easily and grow well here.

Normally, livestock find little food on the timbered sites but are attracted to openings, which produce lush forage. Here the animals may trample or bruise seedlings and can retard timber production for many years.

Seral shrubs can produce considerable summer forage for elk and whitetail deer. These sites may also be important to ruffed grouse and the *Vaccinium* berries are important food for black bear.

Other studies. — The *ABLA/CLUN* h.t. in our area is similar to the *Abies lasiocarpa/Pachistima myrsinites* h.t. of northern Idaho (R. and J. Daubenmire 1968). *Clintonia uniflora* is used to provide a more definitive name than R. and J. Daubenmire's (1968) "*Pachistima* union" because members of this union reach their range limits independently going southward in central Idaho. *ABLA/CLUN* also occurs in northwestern Montana (Pfister and others 1977).

ABIES LASIOCARPA/COPTIS OCCIDENTALIS H.T. (*ABLA/COOC;* SUBALPINE FIR/WESTERN GOLDTHREAD)

Distribution. — This incidental h.t. occurs in minor amounts between the South Fork of the Clearwater and the Salmon River. It ranges from 5,150 to 6,650 feet (1 570 to 2 030 m) at lower to mid-elevations of the *Abies lasiocarpa* zone. Geographically, it appears closely related to the *ABGR/COOC* h.t. and usually occurs in areas where this type is prevalent on warmer aspects. *ABLA/COOC* was found on all but warm southerly exposures and appears slightly drier than the *ABLA/CLUN* h.t.

Vegetation. — *Pinus contorta* followed by *Picea* are the major seral dominants. *Pseudotsuga* and sometimes *Larix* are occasionally present in seral stands. *Menziesia ferruginea* often dominates with a light cover but is seldom vigorous. *Vaccinium globulare* and *Xerophyllum* may also be well represented. *Coptis* is common throughout the stand and is usually accompanied by *Anemone piperi.*

Productivity/Management. — Timber productivity should be nearly as high as that of the *ABLA/CLUN* h.t. and silvicultural treatments should be similar. However, our limited data suggest that wildlife values may be less than in *ABLA/CLUN. Amelanchier, Ribes lacustre,*

Rubus parviflorus, and *Sorbus* are notably absent in this h.t., whereas they all occur frequently in *ABLA/CLUN*.

Other studies. — The *ABLA/COOC* h.t. is described on the Nezperce National Forest (Steele and others 1976, unpubl. ref.).

ABIES LASIOCARPA/MENZIESIA FERRUGINEA H.T. *(ABLA/MEFE;* SUBALPINE FIR/MENZIESIA)

•*Menziesia ferruginea* phase (*MEFE;* menziesia)

**Luzula hitchcockii* phase (*LUHI;* smooth woodrush)

Distribution. — *ABLA/MEFE* is a minor h.t. in the Wallowa-Seven Devils section and in western portions of the Southern Batholith section. It also extends eastward through the Salmon Uplands section into Montana and northward to Canada. It ranges from 5,600 to 7,200 feet (1 710 to 2 200 m) and usually occurs at middle to upper elevations of the *Abies lasiocarpa* zone but may follow cold-air drainages down to 4,500 feet (1 370 m). It tends to occupy moist northerly aspects that are often quite steep and sheltered from extreme sun and wind.

Vegetation. — Usually *Picea* is the major seral dominant. *Pinus contorta, Pseudotsuga,* and occasionally *Larix occidentalis* or *Abies grandis* grow here in minor amounts. *Menziesia* dominates the undergrowth and often forms a tall, dense layer. A diverse group of moist-site herbs grow beneath the shrubs; of these, *Viola orbiculata* and *Pyrola secunda* are the most common.

Luzula hitchcockii (LUHI) phase. — The *LUHI* phase occurs mostly north of our area, but small amounts also appear in the Salmon Uplands section. This phase represents the upper elevations (6,200 to 7,200 feet [1 890 to 2 200 m]) of *ABLA/MEFE* where deep snow may persist later in the growing season. *Luzula hitchcockii* is common throughout the stand and species diversity is slightly less than in the *MEFE* phase. Upper limits of the *LUHI* phase usually border the *ABLA/LUHI* h.t.

Menziesia ferruginea (MEFE) phase. — This is the most common phase in our area. Its description follows that given for the type.

Soil. — The soils are derived mainly from granitics and vary from loam to loamy sand. The pH ranges from 5.1 to 6.2 and averages 5.4 in the *MEFE* phase. The *LUHI* phase should average somewhat less. Areas of bare soil or rock are usually negligible, but boulders and rock outcrops may be present. Litter depths can average at least 9 cm on a site.

Productivity/Management. — Limited data suggest that timber potentials are moderate to high in the *MEFE* phase and somewhat lower in the *LUHI* phase. *Picea* appears productive and though it regenerates easily in openings that receive partial shade, the most vigorous growth is attained in clearcut areas (Roe and DeJarnette 1965). Overstory shade eventually favors *Abies lasiocarpa.* Exposing mineral soil and prescribed burning produce better regeneration than the undisturbed forest floor, scarification being the more effective treatment (Roe and DeJarnette 1965). When the overstory is removed, densities of *Menziesia, Vaccinium,* and other shrubs can increase and retard regeneration of conifers. Where mineral soil is exposed in openings, *Alnus sinuata* can easily invade and remain dominant for many years; however, the nitrogen-fixing capabilities of *Alnus* may be useful on some sites.

Domestic livestock seldom find much forage here, but in the summer and fall, big game, especially elk, benefit considerably from the dense cover and browse. In certain areas, moose, mule deer, black bear and Franklin's grouse also seek food and cover on these sites. In winter, old-growth stands are important habitat for marten (Koehler and Hornocker 1977).

Other studies. — In northern Idaho, R. and J. Daubenmire (1968) describe *ABLA/MEFE* as containing *Xerophyllum tenax* throughout the h.t. In central Idaho, *ABLA/MEFE* extends south of the range of *X. tenax* and so it lacks this species in some areas. The *ABLA/MEFE* h.t. in Montana (Pfister and others 1977) corresponds to our *MEFE* phase; however, our *LUHI* phase apparently reflects the downslope extension of *LUHI* to milder summer environments (because of longer-lasting snowpack) than in Montana. Cooper (1975) reports isolated occurrences of this h.t. in Wyoming's Teton Range.

ABIES LASIOCARPA/ACER GLABRUM H.T. *(ABLA/ACGL;* SUBALPINE FIR/MOUNTAIN MAPLE)

Distribution. — This minor h.t. occurs mainly in southern portions of the Southern Batholith section where it usually occupies moist north to easterly aspects. It ranges from 4,800 to 6,500 feet (1 460 to 1 980 m) at lower elevations of the subalpine zone. Adjacent warmer sites are usually *Pseudotsuga* h.t.'s

Vegetation. — *Pseudotsuga* is the dominant seral tree throughout the h.t. Other seral conifers are rare. In old-growth stands, large spreading *Acer glabrum* usually dominate an undergrowth of declining, less shade-tolerant shrubs. In the forb layer *Thalictrum occidentale, Penstemon wilcoxii,* and the vine, *Clematis columbiana,* occupy the shrub interspaces. Under dense canopies, both the *Penstemon* and *Clematis* can serve as alternate indicators of this h.t. In seral conditions, a thick cover of tall shrubs dominates the undergrowth. *Sorbus, Salix, Prunus,* and *Amelanchier* are the common components of these communities.

Soil. — Parent materials are mainly granitic but also include quartz monzonite and rhyolite (appendix D-1). Textures are mostly loam to fine sandy loam and are occasionally gravelly. The pH ranges from 5.4 to 6.2 and averages 5.8. Areas of bare soil or bare rock are usually less than 5 percent. Average litter depths can reach at least 6 cm on a site. Soils are deep and fertile. Much of this h.t. occupies cryoplanated lands where soil moisture occurs near the surface (John Arnold, USDA Forest Service, retired; personal communication). This moisture apparently transports plant nutrients through the root zone and increases effective fertility in spite of low-nutrient parent materials.

Productivity/Management. — Timber productivity is moderate to high (appendix E-2). *Pseudotsuga* is the most productive species and should regenerate well on carefully prepared sites that benefit from partial shade. Complete overstory removal by fire or logging can produce a tall shrub field that persists for decades and retards conifer seedlings.

Livestock find little forage here, but sheep can feed on the numerous forbs and lower limbs of the tall shrubs. In some brushfields defoliation and trampling by sheep may improve conditions for tree establishment after the sheep are removed.

The seral shrubs in this h.t. have high forage value to elk and mule deer but snow depths usually prevent winter use. The shrubs may also provide food and cover for black bear and blue grouse.

Other studies. — Henderson and others (1976, unpubl. ref.) describe *ABLA/ACGL* in southeastern Idaho and northern Utah. Steele and others (1979, unpubl. ref.) also found it in western Wyoming and classified that entire population the *Pachistima myrsinites* phase. The central Idaho population should be considered as the *Acer glabrum* phase.

ABIES LASIOCARPA/VACCINIUM CAESPITOSUM H.T. *(ABLA/VACA;* SUBALPINE FIR/DWARF HUCKLEBERRY)

Distribution. — This minor h.t. occurs mainly in the Southern Batholith and Salmon Uplands sections. *ABLA/VACA* ranges from 5,200 to 6,700 feet (1 590 to 2 040 m) and occupies flat to gently rolling terrain at middle to lower elevations of the *Abies lasiocarpa* zone. It often occurs on deposits of well-drained glacial outwash in areas that impound cold air. Adjacent sites usually include *ABLA/CACA* h.t., *VACA* phase.

Vegetation. — Stable communities of *Pinus contorta* usually dominate these sites. Seedlings of *P. contorta* are numerous and the trees vary in age distribution. Scattered and often stunted *Picea* and *Abies lasiocarpa* usually occur throughout the stand. The *Abies* reproduction is often vegetative and forms broad patches that prevent establishment of *Pinus contorta.*

As this h.t. approaches more moderate conditions, or sites with greater relief, the *Abies* and *Picea* appear more vigorous and *Vaccinium scoparium* becomes more prevalent. Normally undergrowth is characterized by a layer of *Vaccinium caespitosum* and *Calamagrostis rubescens. Fragaria virginiana, Viola adunca,* and depauperate *Epilobium angustifolium* occur throughout the stand.

Soil. — The soils, though often alluvial, are mainly of granitic origin (appendix D-1). Textures vary from silt loam to loamy sand and are frequently gravelly. Soil pH ranges from 5.1 to 5.7 and averages 5.3. Areas of bare soil or rock are normally less than 1 percent. Average litter depth on a site seldom exceeds 4 cm.

Productivity/Management. — Timber potentials are low to moderate (appendix E-2). *Pinus contorta* is apparently the only species suitable for timber on these sites. It has mostly nonserotinous cones and the seedlings appear to establish quite readily. The gentle terrain makes these sites amenable to intensive silviculture, but no data are available to assure a satisfactory response to silvicultural treatment.

Although the terrain is suitable for grazing, livestock find only light to moderate forage in the form of *Calamagrostis rubescens* and *Carex geyeri.*

Because *ABLA/VACA* often borders moist meadows, elk and mule deer use these sites for cover in summer and fall. These sites may also be important habitat for Franklin's grouse.

In some areas, this h.t. has been developed for campgrounds. Both *Vaccinium caespitosum* and *Calamagrostis rubescens* can withstand light foot traffic, but heavy, uncontrolled use can destroy plant cover and expose soil. The gentle terrain provides easy access and is well suited for campground development; however, knowledgeable campers may prefer areas that receive less frost and fewer mosquitoes, which thrive in adjacent wet sites.

Other studies. — *ABLA/VACA* also occurs in Montana (Pfister and others 1977) and in the Uinta Mountains of Utah (Henderson and others 1977, unpubl. ref.).

ABIES LASIOCARPA/LINNAEA BOREALIS H.T. (*ABLA/LIBO;* SUBALPINE FIR/TWINFLOWER)

•*Linnaea borealis phase (LIBO;* twinflower)

**Vaccinium scoparium* phase (*VASC;* grouse whortleberry)

Distribution. — Minor amounts of *ABLA/LIBO* occur in the Southern Batholith section. It ranges from 5,000 to 7,400 feet (1 520 to 2 260 m) and usually occupies cool gentle terrain at lower to mid-elevations of the subalpine zone.

Vegetation. — *Pinus contorta, Pseudotsuga,* and *Picea* are the major seral dominants. In some areas *Alnus sinuata* forms a dominant layer beneath *Pinus contorta. Linnaea* is common throughout the stand even though other shrubs may create the dominant aspect. Other features vary between the phases noted below.

Linnaea borealis (LIBO) phase. — This phase may occur throughout the range of *ABLA/LIBO. Pseudotsuga, Picea,* and to a lesser extent *Pinus contorta* are the common seral dominants in most of our area. *Alnus sinuata* may dominate undergrowths of seral stands. In older stands, *Vaccinium globulare* may form a light layer and *Linnaea* tends to form a fairly extensive mat.

Xerophyllum tenax (XETE) phase. — This incidental phase occurs mainly in Montana, but one stand was found in adjacent Idaho. This phase is similar to the *LIBO* phase but has an additional layer of *Xerophyllum* in older stands. *Pachistima myrsinites* is also a common associate of *Xerophyllum* in the Montana stands.

Vaccinium scoparium (VASC) phase. — This incidental phase occurs mainly in Montana and Wyoming but appears sporadically in central Idaho. *Pinus contorta* is the most common seral dominant and *Vaccinium scoparium* dominates the undergrowth. *Calamagrostis rubescens* often forms a conspicuous layer with the *Vaccinium,* especially in the more seral situations.

Soil. — Soil parent materials are mainly granitic and occasionally andesite (appendix D-1). Textures are clay loams to fine sandy loams. Soil pH ranges from 5.1 to 6.4 and averages 5.5. Areas of bare soil and rock are negligible although exposed boulders may be present. Average litter depth on a site can reach at least 6 cm.

Productivity/Management. — Limited data suggest that timber potential is moderate, with the *VASC* phase having the lowest productivity. *Pinus contorta* is the most productive conifer in the *VASC* phase and regenerates readily wherever there is ample sunlight. In the *LIBO* phase *Pseudotsuga* and *Picea* should regenerate well in partially shaded openings.

Livestock may be attracted by the gentle terrain of these sites but find mainly *Calamagrostis rubescens* as forage. The animals cause little damage here except for the trampling of conifer seedlings.

ABLA/LIBO can provide escape cover for deer and elk, and the *Vaccinium* fruits may be important feed for grouse and black bear.

Other studies. — Pfister and others (1977) describe *ABLA/LIBO* in Montana; Cooper (1975) notes it in Yellowstone National Park as the *Picea-Abies/Linnaea borealis* h.t. Steele and others (1979, unpubl. ref.) describe *ABLA/LIBO* in the Wind Range of Wyoming.

ABIES LASIOCARPA/ALNUS SINUATA H.T. (*ABLA/ALSI;* SUBALPINE FIR/SITKA ALDER)

Distribution. — This incidental h.t. occurs mainly in Montana but also was found in the vicinity of Salmon, Idaho. It tends to occupy cool northerly aspects in lower portions of the subalpine zone.

Vegetation. — Seral stands are dominated by *Pinus contorta* and usually have lesser amounts of *Picea, Abies lasiocarpa,* and occasionally *Pseudotsuga. Alnus sinuata* forms a dense but patchy layer in the undergrowth. *Xerophyllum, Vaccinium globulare,* or *V. scoparium* may be conspicuous below the *Alnus.* Old-growth stands of *Picea* and *Abies* are rare.

ABLA/ALSI appears most similar to the *ABLA/MEFE* and *ABLA/LIBO* h.t.'s. It is uncertain whether *Alnus sinuata* can persist as the climax dominant but no other species present is an adequate indicator of the moisture regime that occurs here. Although the *Alnus* may not persist in dense stands, it is the only practical interim indicator for these relatively moist, cool sites.

Productivity/Management. — Limited data suggest that timber productivity should be moderate, with *Pinus contorta* as the major species. The pine can regenerate easily in clearings that receive full sunlight, but *Alnus sinuata* will also invade the clearings wherever bare soil occurs and may retard the seedlings. The alder suggests that soils are wet at least part of the year, which may create problems for access and timber harvest. Use by both livestock and big game appears to be light.

Other studies. — Pfister and others (1977) describe *ABLA/ALSI* in Montana where it is more common. R. and J. Daubenmire (1968) and possibly others describe *Alnus sinuata* brushfield and snowslide situations. These should not be confused with our definition of *ABLA/ALSI.*

ABIES LASIOCARPA/XEROPHYLLUM TENAX H.T. (*ABLA/XETE;* SUBALPINE FIR/BEARGRASS)

• *Vaccinium scoparium* phase (*VASC;* grouse whortleberry)

★ *Vaccinium globulare* phase (*VAGL;* blue huckleberry)

✻ *Luzula hitchcockii* phase (*LUHI;* smooth woodrush)

Distribution. — *ABLA/XETE* occurs mainly in the Salmon Uplands section. It ranges from 6,000 to 8,300 feet (1 830 to 2 530 m) and occupies various slopes and aspects from middle to upper elevations of the subalpine zone. Occasionally it extends into the lower subalpine (5,400 feet [1 650 m]).

Vegetation. — *Pinus contorta* is the most common seral dominant of these sites. In some areas, *Picea* and occasionally *Pseudotsuga* are also major seral trees. Various amounts of *Vaccinium globulare* and *Vaccinium scoparium* may codominate with *Xerophyllum.*

Vaccinium globulare (VAGL) phase. — This phase delineates the more moderate segment (5,400 to 7,000 feet [1 650 to 2 130 m]) of the h.t. *Pseudotsuga* is more common in this phase and *Picea* often attains higher coverages and appears more vigorous. *Vaccinium*

globulare usually codominates the undergrowth with *Xerophyllum*. *Sorbus scopulina* and *Spiraea betulifolia* are often present in small amounts.

Vaccinium scoparium (VASC) phase. — The *VASC* phase tends to occur along the southern and eastern periphery of the *ABLA/XETE* distribution and delineates the upper elevations (6,500 to 8,300 feet [1 980 to 2 530m]) of the h.t. in these areas. In seral stands, *Pinus contorta* is the major dominant; small amounts of *Picea* are usually present. *Vaccinium scoparium* usually dominates between the clumps of *Xerophyllum*, which are often widely spaced.

Luzula hitchcockii (LUHI) phase. — The *LUHI* phase denotes upper elevations (6,100 to 7,800 feet [1 860 to 2 380 m]) of *ABLA/XETE* within the more central portions of its distribution. Upper limits of this phase tend to merge with the *ABLA/LUHI* h.t. *Pinus contorta* dominates seral stands and small amounts of *Pinus albicaulis* are usually present. Undergrowths are a mixture of *Xerophyllum* and *Vaccinium scoparium*, with patches of *Luzula hitchcockii*.

Soil. — Soil parent materials are mostly granitic but include some quartzite, andesite, and schist (appendix D-1). Textures are mainly loam to sandy loam and are often gravelly, especially in the *VASC* phase. The pH ranges from 4.5 to 5.9 and averages 5.0. Areas of bare rock are usually less than 5 percent, but occasionally exposed boulders amount to 30-percent coverage. Most sites have less than 5 percent bare soil. Average litter depth on a site can reach 6 cm.

Productivity/Management. — Timber potential appears low in the *LUHI* phase and is generally moderate in the *VASC* and *VAGL* phases (appendix E). *Pinus contorta* is usually the most productive species and regenerates well in clearings that receive full sunlight. Occasionally *Picea* or *Pseudotsuga* are suitable timber species in the *VAGL* phase.

Livestock find little forage in this h.t. but may congregate in clearings and reduce survival of tree seedlings. In summer and fall, these sites can provide forage and cover for deer and elk. The *Vaccinium* fruits are usually important to black bear, blue grouse, and Franklin's grouse.

Many of the sites accumulate a considerable snowpack each year and are often visited by recreationists during the summer.

Other studies. — In northern Idaho, R. and J. Daubenmire (1968) describe *ABLA/XETE* as usually lacking *Picea*. Otherwise their stands (except No. 57) are comparable to our *VAGL* phase. In Montana, Pfister and others (1977) describe comparable *VAGL* and *VASC* phases but place those stands having *Luzula hitchcockii* present in the *ABLA/LUHI* h.t. About half of the *ABLA/XETE* sites sampled in central Idaho contain *L. hitchcockii* in various amounts. In our area, it appears that the *Luzula* occupies sites at lower relative elevations of the subalpine zone than in Montana. Thus, we feel justified in defining the *LUHI* phase to distinguish these sites from the *ABLA/LUHI* h.t. described in Montana. Both Horton (1971, unpubl. ref.) and Cooper (1975) mention isolated outposts of *ABLA/XETE* in northwestern Wyoming.

***ABIES LASIOCARPA/VACCINIUM GLOBULARE* H.T. *(ABLA/VAGL;* SUBALPINE FIR/BLUE HUCKLEBERRY)**

• *Vaccinium globulare* phase *(VAGL;* blue huckleberry)

* *Vaccinium scoparium* phase *(VASC;* grouse whortleberry)

Distribution. — *ABLA/VAGL* occurs mainly in the Southern Batholith section from 5,100 to 7,300 feet (1 550 to 2 230 m). It occupies north-to-easterly aspects at lower to mid-elevations of the subalpine zone and often borders *Pseudotsuga* h.t.'s.

Vegetation. — Depending on the phases described below, *Pseudotsuga*, *Picea*, or *Pinus contorta* dominate seral stands. *Vaccinium globulare* forms a dominant layer in the undergrowth and is usually accompanied by *Lonicera utahensis* (fig. 29). In many respects these sites resemble *ABLA/XETE*, except that *Xerophyllum* is absent.

Vaccinium globulare (VAGL) phase. — This is the common phase in our area. *Pseudotsuga* and *Picea* are the seral dominants. *Pinus contorta* also grows here but in lesser amounts. This phase is similar to the *VAGL* phase of *ABLA/XETE* but lacks *Xerophyllum*.

Vaccinium scoparium (VASC) phase. — This is an incidental phase in our area but becomes common in western Wyoming. It represents an upper elevation segment of *ABLA/VAGL* and often borders *ABLA/VASC*. *Pinus contorta* followed by *Picea* are the common seral

Figure 29. — Abies lasiocarpa/Vaccinium globulare h.t. on a north exposure northwest of Rocky Bar, Idaho (7,300 feet [2 230 m] elevation). Abies lasiocarpa *and scattered* Picea engelmannii *dominate the site.* Vaccinium globulare *forms a dominant layer in the undergrowth.*

dominants. Here, the *Vaccinium globulare* is normally superimposed on a layer of *V. scoparium.*

Soil. — Soil parent materials are mostly granitics but also include quartz monzonite, rhyolite, and metasediments (appendix D-1). Textures are mostly loams or sandy loams and are often gravelly. The pH ranges from 5.0 to 6.2 and averages 5.5. Areas of bare soil or bare rock are usually less than 3 percent. Average litter depth on a site can reach at least 5 cm.

Productivity/Management. —Timber potentials are moderate in the *VAGL* phase (appendix E-2) and appear to be somewhat lower in the *VASC* phase. *Picea* and *Pseudotsuga* are the best suited timber species for the *VAGL* phase and should regenerate in small clearings that receive partial shade. *Pinus contorta* is best suited for the *VASC* phase and regenerates well in clearings that receive full sunlight. When the tree canopy is reduced, *Vaccinium globulare* may increase and compete with conifer seedlings, especially toward the moist extreme of this h.t.

Livestock find very little forage in this h.t. and seldom spend much time here.

These sites can provide cover and some forage for elk and mule deer in summer and fall. The berry crops of *Vaccinium* are used by black bear, grouse, and humans.

Other studies. — The *ABLA/VAGL* h.t. also occurs in southern Montana, eastern Idaho, and northwestern Wyoming (Cooper 1975; Steele and others 1979, unpubl. ref.). In northern Utah, and adjacent Idaho, Henderson and others (1976, unpubl. ref.) describe a very similar condition as the *Abies lasiocarpa/Vaccinium membranaceum* h.t. and Hall (1973) mentions a "subalpine fir-big huckleberry community type" in eastern Oregon.

ABIES LASIOCARPA/SPIRAEA BETULIFOLIA H.T. (*ABLA/SPBE;* SUBALPINE FIR/WHITE SPIRAEA)

Distribution. — *ABLA/SPBE* occurs mainly in the Southern Batholith section, from 5,300 to 7,200 feet (1 620 to 2 200 m). It is a relatively minor h.t. and represents a warm, dry extreme of the *Abies lasiocarpa* series. It usually occupies northerly aspects where the *Pseudotsuga* series occurs on adjacent sites.

Vegetation. — *Pseudotsuga* and *Pinus contorta* are the major seral dominants. *Spiraea betulifolia* usually dominants the undergrowth even though taller shrubs may be present. On some sites, *Carex geyeri* or *Calamagrostis rubescens* forms a layer beneath the *Spiraea.*

Soil. — Soil parent materials are mainly granitic or quartz monzonite (appendix D-1). Textures range from loam to loamy sand and are often gravelly. Soil pH varies from 5.3 to 6.2 and averages 5.7. Areas of bare soil are usually negligible, but bare rock may reach 20 percent. Average litter depths on a site may reach 4 cm.

Productivity/Management. — Timber potential is low to moderate (appendix E-2). *Pseudotsuga* usually grows best on these sites and should regenerate in small clearings that receive partial shade. If present, *Pinus contorta* will regenerate in unshaded clearings, but its productivity may be less than *Pseudotsuga.*

Livestock find little forage on these sites except when *Carex geyeri* or *Calamagrostis rubescens* are present.

Mule deer and occasionally elk find cover and some forage here in summer and fall. Seral stands can produce some shrubs with high forage value to big game. In spring and summer, *ABLA/SPBE* is considered important habitat for red squirrel, flying squirrel, red-backed vole, and marten. It is also considered as nesting habitat for pine siskin, dark-eyed junco, mountain chickadee, and red-breasted nuthatch.

Other studies. — *ABLA/SPBE* is reported in western Wyoming and adjacent Idaho (Steele and others 1979, unpubl. ref.). It also resembles Cooper's (1975) *ABLA/VAGL* h.t., *SPBE* phase in the same area.

ABIES LASIOCARPA/LUZULA HITCHCOCKII H.T. (*ABLA/LUHI;* SUBALPINE FIR/WOODRUSH)

•*Luzula hitchcockii phase* (*LUHI;* smooth woodrush)

**Vaccinium scoparium* phase (*VASC;* grouse whortleberry)

Distribution. — *ABLA/LUHI* occurs mainly in the Salmon Uplands section and occasionally southward. It ranges from 7,000 to 8,200 feet (2 130 to 2 500 m) and appears at middle to upper elevations of the subalpine zone. It occupies cold sites that retain a snow cover late into the summer and often occurs near cirque headlands wherever the soil escaped glacial scouring.

Vegetation. — *Picea, Pinus contorta,* and *P. albicaulis* are considered the major seral dominants, but because succession is slow and often interrupted *Picea* and *Pinus albicaulis* are seldom completely replaced in the stand. *Arnica latifolia, Chionophila tweedyi,* and *Pedicularis contorta* are characteristic forbs of an undergrowth often dominated by *Luzula hitchcockii* or *Vaccinium scoparium.*

Vaccinium scoparium (VASC) phase. — This phase is the most common and it occurs throughout the range of the h.t. Normally, *Vaccinium scoparium* dominates the undergrowth and *Luzula* occupies the shrub interspaces.

Luzula hitchcockii (LUHI) phase. — The *LUHI* phase occurs mostly near upper timberline and often borders sites having *Juncus parryi* as the dominant undergrowth. *Pinus albicaulis* is often the only major seral dominant and, on some sites, may codominate in stable stands. *Luzula hitchcockii* usually forms a thick

Figure 30. — Abies lasiocarpa/Luzula hitchcockii h.t., Luzula hitchcockii phase on a gentle, northerly exposure near Kenneth Lake north of McCall, Idaho (7,500 feet [2 290 m] elevation). Abies lasiocarpa dominates the site. Luzula hitchcockii forms a notable layer in the undergrowth.

sod and dominates the undergrowth (fig. 30). Patches of *Veratrum viride* or *Polygonum phytolaccaefolium* may appear in disturbed areas.

Soil. — The soils are derived mainly from granitics and sometimes andesite (appendix D-1). They vary from loam to fine sandy loam and a few are gravelly. In the *LUHI* phase, soil pH ranges from 4.3 to 5.0 and averages 4.6. In the *VASC* phase it ranges from 4.9 to 5.2 and averages 5.0. In both phases, coverage of bare rock is usually less than 5 percent, but exposed boulders may reach 50 percent. Areas of bare soil are mostly less than 10 percent. Average litter depths can reach at least 3 cm.

Productivity/Management. — Limited data suggest timber potentials are low and it may be difficult to achieve tree regeneration after logging. Heavy snowpacks often deform the smaller trees and regeneration of *Abies lasiocarpa* may be largely vegetative.

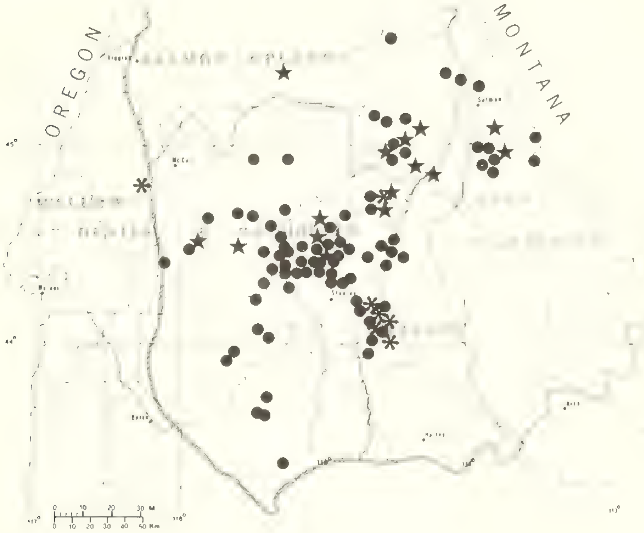
Livestock find little forage here; but in the past, domestic sheep trailed across these sites and destroyed the *Luzula* sod. In some areas, the bared soil was then eroded by melting snowpacks.

In summer and fall, *ABLA/LUHI* provides cover and forage for elk, mule deer, mountain goat, and in some areas bighorn sheep. In fall and winter, these sites are important to blue grouse, which feed on the leaves and buds of *Abies lasiocarpa.*

The depth and persistence of snow in this h.t. indicates that water is a key resource for management consideration.

Other studies. — In Montana, Pfister and others (1977) define a somewhat broader *ABLA/LUHI* h.t. (see the discussion of our *LUHI* phase in the *ABLA/XETE* and *ABLA/MEFE* h.t.'s). In Wyoming, Cooper (1975) mentions small areas of this h.t. in the Teton Range.

ABIES LASIOCARPA/VACCINIUM SCOPARIUM H.T. (*ABLA/VASC;* SUBALPINE FIR/GROUSE WHORTLEBERRY)



• *Vaccinium scoparium phase* (*VASC;* grouse whortleberry)

★ *Calamagrostis rubescens* phase (*CARU;* pinegrass)

✻ *Pinus albicaulis* phase (*PIAL;* whitebark pine)

Distribution. — *ABLA/VASC* occurs mainly in the Southern Batholith section. It ranges from 6,600 to 9,200 feet (2 010 to 2 800 m) at middle to upper elevations of the subalpine zone and occupies a variety of slopes and aspects. Occasionally it follows cold-air drainages into lower elevations (5,700 feet [1 740 m]).

Vegetation. — *Pinus contorta* dominates seral stands throughout most of this h.t. *Picea* and *Pseudotsuga* are often present as minor species. *Pinus albicaulis* appears in various amounts and ranges from seral at the warm extreme to coclimax at the cold extreme. A low cover of *Vaccinium scoparium* dominates the undergrowth (fig. 31). Other shrubs, if present, are usually sparse and well scattered. A few forbs such as *Arnica, Lupinus,* and *Valeriana* are usually present.

Calamagrostis rubescens (CARU) phase. — At lower elevations (5,700 to 7,500 feet [1 740 to 2 290 m]) of the *ABLA/VASC* h.t., *Calamagrostis rubescens* codominates the undergrowth with *Vaccinium.* Here *Pseudotsuga* may appear as a major seral tree and codominate the stand with *Pinus contorta.* Warm, dry extremes of this phase often border *ABLA/CARU* or *PSME/CARU.*

Vaccinium scoparium (VASC) phase. — This phase is the most common and represents the middle segment (6,600 to 8,900 feet [2 010 to 2 710 m]) of the h.t. *Pinus contorta* dominates most seral stands and *Picea* is usually present in minor amounts. Replacement by *Abies lasiocarpa* is quite slow. This phase has a conspicuous moss layer more frequently than the other phases. The most common mosses are *Brachythecium velutinum* and *Polytricadelphus lyallii* (Steele 1974).

Pinus albicaulis (PIAL) phase. — This phase appears in the upper elevations (7,100 to 9,200 feet [2 160 to 2 800 m]) of the h.t. It is scarce in central Idaho but becomes more common eastward into Montana and Wyoming. *Pinus albicaulis* usually codominates the stand with *Abies lasiocarpa, Pinus contorta,* and *Picea.* These stands appear more open than in the other phases and apparently afford *Pinus albicaulis* a permanent role in the forest community. Upper limits of this phase often border *PIAL-ABLA* h.t.'s. This phase is comparable to the *ABLA-PIAL/VASC* h.t. defined for Montana (Pfister and others 1977).

Soil. — Soil parent materials vary considerably and usually reflect overall geology of the area. They include granitics, quartzite, quartz monzonite, diorite, trachyte, latite, andesite, and basalt (appendix D-1). Soil textures are loam to sandy loam and are often gravelly. The pH ranges from 4.7 to 5.7 and averages 5.1. Coverage of bare rock is usually less than 5 percent but can reach 15 percent. Areas of bare soil are less than 5 percent. Average litter depths can reach at least 5 cm.

Productivity/Management. — Timber potentials are moderate in the *VASC* phase (appendix E-2). (Limited data suggest low productivity in the *PIAL* phase and low-to-moderate productivity in the *CARU* phase.) *Pinus contorta* is the most suitable timber species and will regenerate in unshaded clearings. Attempts to regenerate other species assume considerable risk. In the *CARU* phase, coverages of *Calamagrostis rubescens* and *Carex geyeri* may impede tree regeneration unless there is thorough site preparation. However, soil scarification may increase hazards to frost heaving.

Livestock find little forage here due to short growing seasons, limited numbers of forage species, and shade of the tree canopy.

In fall, *ABLA/VASC* can provide escape cover for elk and mule deer and the *Vaccinium* fruits are important food for both blue and Franklin's grouse. It is considered important habitat for snowshoe hare, flying squirrel, red squirrel, red-backed vole, porcupine, marten, and lynx. It also provides important nesting habitat for the red crossbill, dark-eyed junco, mountain chickadee, and red-breasted nuthatch.

Annual snowpacks may produce high quantities of water in certain watersheds and recreational summer use may also be quite high.

Other studies. — *ABLA/VASC* is a widespread h.t. throughout the Northern Rockies except for areas in northern Idaho and adjacent Montana where the maritime influence is strongest. R. and J. Daubenmire (1968) describe *ABLA/VASC* in eastern Washington and

Figure 31. — Abies lasiocarpa/Vaccinium scoparium *h.t.,* Vaccinium scoparium *phase on a gentle northerly exposure east of Lowman, Idaho (7,200 feet [2 200 m] elevation).* Abies lasiocarpa *is regenerating beneath an overstory of* Pinus contorta. Vaccinium scoparium *dominates the undergrowth.*

northeastern Oregon and note its occurrence in British Columbia, Montana, and Colorado. Hall (1973) records similar situations in eastern Oregon. In Montana, Pfister and others (1977) report this h.t. as being very abundant and delineate three phases. Cooper (1975) and Steele and others (1979, unpubl. ref.) report a prevalence of *ABLA/VASC* in western Wyoming. It is also descrbed in Wyoming's Medicine Bow (Wirsing and Alexander 1975), and Bighorn (Hoffman and Alexander 1976) Mountains, the Uinta Mountains in northeastern Utah (Pfister 1972; Henderson and others 1977, unpubl. ref.) and the front range of Colorado (Marr 1961; Moir 1969).

ABIES LASIOCARPA/CALAMAGROSTIS RUBESCENS H.T. (*ABLA/CARU;* SUBALPINE FIR/PINEGRASS)

Distribution. — *ABLA/CARU* is most common in the Southern Batholith section. Here it occupies gentle upper slopes and ridges and, under certain soil conditions, stream terraces and valley floors. It ranges from 6,400 to 8,900 feet (1 950 to 2 710 m) in elevation and normally occurs from lower to mid-elevations of the subalpine zone. At the warm extreme it usually merges with *PSME/CARU.*

Vegetation. — *Pinus contorta* is the major seral dominant throughout the h.t., and *P. albicaulis* may appear in minor amounts. *Pseudotsuga* may also dominate seral stands at the warm extremes of this type. *Calamagrostis rubescens* often accompanied by *Carex geyeri* dominates the undergrowth. *Symphoricarpos oreophilus* and other shrubs are often present but very scattered. Forbs are usually sparse on undisturbed sites.

Soil. — Soil parent materials are mostly granitic but also include quartz monzonite, trachyte, and basalt (appendix D-1). The textures vary from loam to loamy sand and may be gravelly to very gravelly. Soil pH ranges from 4.9 to 6.1 and averages 5.4. Areas of bare soil or bare rock are usually less than 5 percent. Average litter depth on a site can reach 3 cm.

Productivity/Management. — Timber potentials are low to moderate (appendix E-2). If present, *Pinus contorta* is the most dependable species for timber management and should regenerate in clearings that have ample sunlight. Attempts to establish other conifers are risky and should be guided by patterns and frequency of regeneration in the stand. If the overstory is removed, the *Calamagrostis* and *Carex* may increase rapidly and retard seedling establishment. Normally livestock use these sites only lightly but are attracted to recent clearings where the forbs and graminoids have renewed vigor. Here the animals may congregate and trample tree seedlings.

Elk and mule deer use these sites for cover in summer and fall and the elk will also feed on the graminoids present. Seral stands may produce some shrubs and forbs with light forage value to deer and elk. These sites are also considered important for red-breasted nuthatch and, in some areas, great gray owl.

Other studies. — This h.t. has been described in Montana (Pfister and others 1977), southern Idaho and adjacent Utah (Henderson and others 1976, unpubl. ref.), and in eastern Idaho and western Wyoming (Steele and others 1979, unpubl. ref.).

ABIES LASIOCARPA/CAREX GEYERI H.T. (*ABLA/CAGE;* SUBALPINE FIR/ELK SEDGE)

•*Carex geyeri* phase (*CAGE;* elk sedge)

★ *Artemisia tridentata* phase (*ARTR;* big sagebrush)

Distribution. — *ABLA/CAGE* occurs widely in the Southern Batholith section and to a lesser extent in the Challis section. It usually ranges from 7,300 to 9,200 feet (2 230 to 2 800 m) where it occupies various aspects at middle to upper elevations of the subalpine zone. Occasionally it extends down to 6,600 feet (2 010 m) in frost pockets that occur on dry stream terraces and valley floors. It may merge with *PSME/CAGE* at its warm extreme and the *PIAL-ABLA* zone at the cold extreme.

Vegetation. — *Pinus contorta* is the most common seral dominant of this h.t. Toward the warm extreme, *Pseudotsuga* may also be a seral dominant. *Picea* and *Pinus albicaulis* appear sporadically throughout the

Figure 32. — Abies lasiocarpa/Carex geyeri h.t., Carex geyeri phase on a southeast exposure near Dollarhide Summit west of Ketchum, Idaho (8,700 feet [2 650 m] elevation). An open stand of Abies lasiocarpa *and scattered* Pinus albicaulis *dominate the site.* Carex geyeri *dominates the undergrowth.*

type with *P. albicaulis* showing increasing abundance toward the cold extreme. *Carex geyeri* dominates the herb layer of undisturbed sites and forbs are usually scarce (fig. 32). Under certain conditions *Artemisia tridentata* and occasionally *Symphoricarpos oreophilus* create a shrub layer. In some areas, *Polygonum phytolaccaefolium* increases notably after disturbance.

Carex geyeri (CAGE) phase. — This is the most common phase of the h.t. Its description fits that given above.

Artemisia tridentata (ARTR) phase. — This phase constitutes a high-elevation variant of *ABLA/CAGE* and is often transitional to nonforested communities near the *PIAL-ABLA* zone. *Pinus albicaulis* is usually the dominant seral species and may even persist as coclimax. Lesser amounts of *Pseudotsuga* and *Pinus contorta* may be present. On many sites the trees grow in clusters pioneered by *Pinus albicaulis* and appear incapable of independent invasion on the site. *Artemisia tridentata* ssp. *vaseyana* forms a shrub layer and its density appears to have increased as the *Carex* sod was destroyed by past grazing abuse. Occasionally *Symphoricarpos oreophilus* codominates with the *Artemisia.*

Soil. — Soil parent materials are largely granitic but also include quartzite, monzonite, dacite, trachyte, rhyolite, andesite, and basalt (appendix D-1). The textures are loam to loamy sand and are almost always gravelly to very gravelly. The pH ranges from 4.6 to 6.4 and averages 5.5. Bare rock usually has less than 5 percent coverage but may reach 20 percent. Areas of bare soil are often 5-10 percent and may reach 40 percent from past grazing abuse. Average litter depth on a site seldom exceeds 4 cm.

Productivity/Management. — Timber potentials are low to moderate (appendix E-2). *Pinus contorta,* when present, is the only practical tree for regeneration but its site index is relatively low. *Pseudotsuga,* if present, usually grows slowly and reproduces sporadically. In the *ARTR* phase, *Pinus albicaulis* is more prevalent

than *P. contorta,* but its production is low and its regeneration is marginal.

Livestock find little forage here except for *Carex geyeri.* In some areas, disturbing the *Carex* sod permits invasion of forbs and grasses but quite often such disturbance provides little forage and increases erosion hazards. Generally these soils are easily eroded and difficult to revegetate.

In general, elk and mule deer use these sites for cover in summer and fall and the elk may feed on the *Carex.* These sites may also be important for both blue and Franklin's grouse. In certain areas the *ARTR* phase provides habitat for mountain goats and bighorn sheep and the elk reportedly use these sites for calving. Because the *ARTR* phase often occurs on ridges, it provides important perching and foraging habitat for blue grouse and birds of prey.

Other studies. — Minor amounts of *ABLA/CAGE* occur in Montana (Pfister and others 1977). It also appears in the Medicine Bow Range of Wyoming (Wirsing and Alexander 1975) and near the Idaho-Wyoming border (Cooper 1975). In the Blue Mountains of Oregon, Hall (1973) describes a similar situation that conforms mostly to our *ARTR* phase.

ABIES LASIOCARPA/JUNIPERUS COMMUNIS H.T. *(ABLA/JUCO;* SUBALPINE FIR/COMMON JUNIPER)

Distribution. — *ABLA/JUCO* occurs mainly in the eastern half of central Idaho. It ranges from 7,400 to 8,600 feet (2 260 to 2 620 m) at mid-elevations of the subalpine zone. Occasionally it follows cold-air drainages into lower elevations (6,700 feet [2 040 m]) where it occupies toe-slopes and dry stream terraces. Lower limits of *ABLA/JUCO* may merge with *ABLA/-ARCO* where only the coverage of *Juniperus* provides an often arbitrary delineation.

Vegetation. — *Pinus contorta* and *Pseudotsuga* are the major seral conifers. Occasionally *Picea* is present. Large, widely spaced patches of *Juniperus communis* create the dominant aspect of the undergrowth. *Arnica cordifolia* usually dominates the forb layer which is often quite depauperate. In some seral stands, *Shepherdia canadensis* forms a persistent shrub layer which may obscure the *Juniperus.* Mosses form a notable layer in some stands; *Brachythecium collinum, Dicranoweisia crispula,* and *Tortula ruralis* are the most common species (Steele 1974).

Soil. — Soil parent materials are mostly quartzite but also include trachyte and dacite (appendix D-1). Textures vary from loam to sandy loam and are usually gravelly to very gravelly. The pH ranges from 5.6 to 7.9 and averages 6.0. Coverage of bare rock is often 10-15 percent and may reach 60 percent. Areas of bare soil are usually negligible but occasionally reach 15 percent. Average litter depth on a site seldom exceeds 4 cm.

Productivity/Management. — Timber potentials are low (appendix E-2) and management alternatives are limited. If present, *Pinus contorta* may establish in clearings that receive adequate sunlight but its production is usually low. When *P. contorta* is absent, timber harvests of other species should be guided by patterns and frequency of natural regeneration.

Livestock find little forage here and seldom use this h.t. except when it occurs on benches or dry stream terraces.

ABLA/JUCO can provide cover for elk and mule deer that feed on other sites nearby. Seral stands may produce *Shepherdia canadensis,* which is occasionally browsed in some areas.

Other studies. — This h.t. is not described elsewhere although its presence is noted in western Wyoming (Steele and others 1979, unpubl. ref.)

ABIES LASIOCARPA/RIBES MONTIGENUM H.T. (*ABLA/RIMO*; SUBALPINE FIR/MOUNTAIN GOOSEBERRY)

Distribution. — *ABLA/RIMO* occurs as a minor type in the Challis and Open Northern Rockies sections. It appears from 8,400 to 9,800 feet (2 560 to 2 990 m) at upper elevations of the forest zone. It may occupy various slopes but is usually on northerly aspects.

Vegetation. — *Pinus albicaulis* and *Abies lasiocarpa* codominate most sites in our area. Small amounts of *Picea* or *Pseudotsuga* may be present. *Picea* becomes increasingly prevalent to the south and east. Undergrowths are often very depauperate. *Ribes montigenum* is the most conspicuous shrub and may form a sprawling cover.

Soil. — Soil parent materials include quartzite, sandstone, and limestone (appendix D-1). Textures vary from loam to sandy loam and are usually gravelly. Areas of bare soil or rock may reach 15 to 20 percent. Average litter depth on a site may reach 5 cm.

Productivity/Management. — Limited data suggest that timber productivity is low to very low (appendix E-1), and regeneration may be sporadic. Large clearings in the stand may subject tree seedlings to damage from frost heaving and extreme sunlight. Recovery from any disturbance is apt to be very slow.

Both big game and livestock may seek shelter on these sites but find very little forage. Snowpacks persist late into the growing season and, in some areas, may be the most valuable resource present.

Other studies. —Pfister (1972) first described *ABLA/RIMO* in Utah and Henderson and others (1976 and 1977, unpubl. ref.) describe three phases from this area. It is also reported in southern Montana (Pfister and others 1977) and western Wyoming (Steele and others 1979, unpubl. ref.).

ABIES LASIOCARPA/ARNICA CORDIFOLIA H.T. (*ABLA/ARCO*; SUBALPINE FIR/HEARTLEAF ARNICA)

Distribution. — *ABLA/ARCO* occurs mainly in the Challis and Open Northern Rockies sections but encroaches into the Southern Batholith section. It ranges from 7,100 to 8,800 feet (2 160 to 2 680 m) and usually occupies northerly to easterly aspects at lower to mid-elevations of the subalpine zone.

Vegetation. — *Pinus contorta* may dominate seral stands but more often *Pseudotsuga* or *Picea* dominate and form dense overstories. *Shepherdia canadensis* occasionally dominates the undergrowth in seral stands but usually shrubs are sparse in most of the later successional stages. Small amounts of *Juniperus communis* and *Symphoricarpos oreophilus* may also be present in the stand. *Arnica cordifolia* normally dominates the forb layer (fig. 33) and *Pyrola secunda* may codominate with the *Arnica*. Some stands have a notable moss layer in which *Brachythecium collinum* and *Dicranoweisia crispula* are the characteristic species (Steele 1974).

Soil. — Soil parent materials are mainly quartzite but include dacite, trachyte, latite, and quartz monzonite (appendix D-1). Textures are loam to sandy loam and most are gravelly to very gravelly. The pH ranges from 4.7 to 6.3 and averages 5.5. Areas of bare rock or bare soil vary considerably among stands and may reach 20 percent. Average litter depth on a site can reach 3 cm.

Productivity/Management. — Timber potentials are low to moderate (appendix E-2). Even though these may be the most productive sites in the area, management alternatives are limited. If present, *Pinus contorta* should regenerate in clearings that receive ample sunlight. When *P. contorta* is absent, timber harvest should be guided by the natural patterns and frequency of regeneration in the stand.

Figure 33. — Abies lasiocarpa/Arnica cordifolia *h.t. on a northerly exposure in the Lemhi Mountains west of Leadore, Idaho (7,900 feet [2 410 m] elevation).* Pseudotsuga menziesii, Pinus contorta, *and* Pinus albicaulis *dominate the site but the regeneration is mainly* Abies lasiocarpa *and a few* Picea engelmanii. Arnica cordifolia *is the dominant forb in the undergrowth.*

Livestock seldom find much forage here but may use these sites for shelter.

ABLA/ARCO provides little forage for big game, but elk and mule deer that feed in adjacent areas will use these sites for thermal and hiding cover.

Other studies. — *ABLA/ARCO* occurs in Montana (Pfister and others 1977) and along the Idaho-Wyoming border (Cooper 1975). It is also described in Wyoming's Bighorn Mountains (Hoffman and Alexander 1976) and in western Wyoming (Steele and others 1979, unpubl. ref.).

PINUS ALBICAULIS-ABIES LASIOCARPA H.T.'s (*PIAL-ABLA;* WHITEBARK PINE-SUBALPINE FIR)

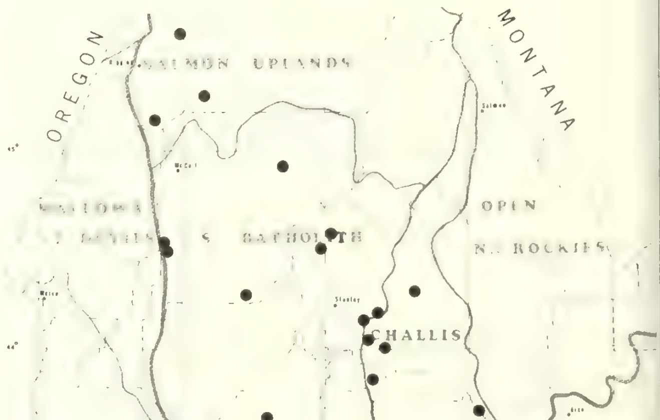


Figure 34. — A Pinus albicaulis-Abies lasiocarpa *h.t. on a steep southwest exposure on Gospel Hill southeast of Grangeville, Idaho (7,700 feet [2 350 m] elevation).* Pinus albicaulis *and* Abies lasiocarpa *codominate the site and neither appears capable of outcompeting the other. In the undergrowth,* Juncus parryi *is most prevalent but* Festuca idahoensis, Luzula hitchcockii, *and* Pedicularis contorta *are also common.*

Distribution. — *PIAL-ABLA* h.t.'s include upper timberline sites across much of central Idaho, especially in the Southern Batholith and Salmon Uplands sections. The complex occurs from 7,700 to 9,400 feet (2 350 to 2 870 m) on a variety of slopes and aspects. A plural designation (h.t.'s) is used for the complex because of considerable variation in tree life-form and undergrowth composition. Individual h.t.'s are not recognized at this time because of the data requirements and the apparent lack of need for management applications at a more detailed level.

Vegetation. — Clusters of *Pinus albicaulis* and *Abies lasiocarpa* codominate most sites in this group (fig. 34). *Pinus contorta* and *Picea* are seldom present and *Pinus flexilis* is absent. The trees are often deformed by severe wind or heavy snowpack. With increasing elevation, the trees become increasingly deformed and appear as widely scattered patches amidst alpine tundra. With lower elevations, the trees show improved growth form and vigor and their canopies gradually converge. Here, undergrowth dominants of *Abies lasiocarpa* forests also appear with increasingly regularity and coverage.

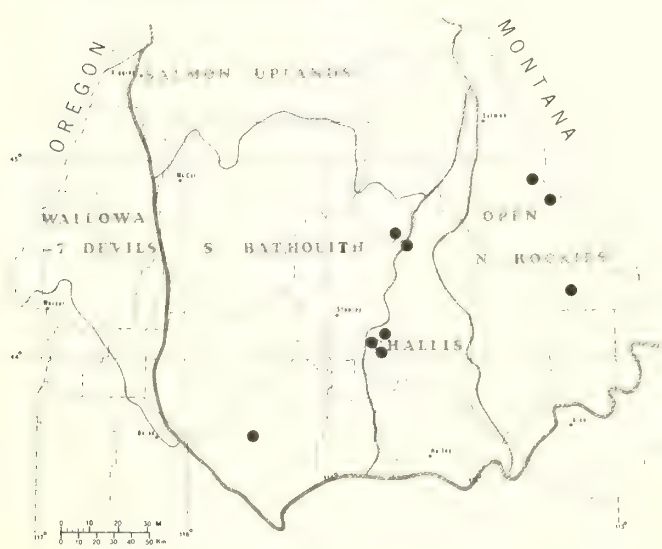
Within the undergrowth complex, at least two conditions show some evidence of representing different h.t.'s and a few others are suspect. Windward aspects exposed to intense sunlight are dominated by grasses. The sites farthest removed from areas of heavy grazing have undergrowths dominated by *Festuca idahoensis.* Similar sites elsewhere have *Stipa occidentalis* as the dominant grass. Leeward aspects that accumulate considerable snow may be dominated by *Juncus parryi,* with *Chionophila tweedyi* as a common forb. In some areas, the cover of *Juncus* may appear as ribbons along the contours as a reflection of past sheep use. In other areas, sheep have obliterated evidence of environmental relationships and have caused erosion that has permanently degraded the site. In many areas, where these conditions prevail, *Polygonum phytolaccaefolium* is now the undergrowth dominant.

Soil. — Soil parent materials are mostly granitic but include quartzite, quartz monzonite, and trachyte (appendix D-1). Textures vary from loam to loamy sand and are usually gravelly to very gravelly. The pH ranges from 4.3 to 5.6 and averages 4.9. Areas of bare rock and bare soil can be quite high, 60 and 80 percent, respectively, but past grazing has aggravated this condition and it is now difficult to characterize natural condition of the ground surface. Litter depths on a site can average up to 4 cm beneath the tree canopy.

Productivity/Management. — The *PIAL-ABLA* h.t.'s apparently have low to very low timber potential (appendix E-1) but may have high watershed value. Forage production may sustain light grazing, but in many areas grazing abuse has decimated the forage and exposed the soil. The vegetation recovers very slowly and, in some areas, soil loss may prevent complete restoration. The open slopes with light undergrowth afford easy travel and the surrounding scenery has considerable esthetic appeal. Hence recreationists seek these areas for hiking and camping but, if concentrated, these activities can easily disrupt soils and vegetation. In some areas, these sites provide important food and cover for mountain goats and bighorn sheep. The sheep also use these sites for lambing and rearing. Elk and mule deer find food and cover here and the elk will feed in the swards of *Festuca idahoensis* found in some areas. *PIAL-ABLA* h.t.'s may also be important wintering areas for blue grouse.

Other studies. — In northern Idaho, R. and J. Daubenmire (1968) noted similar situations. Their description resembles best the lower extremes of our *PIAL-ABLA* zone. In Montana, Pfister and others (1977) describe comparable conditions although *Picea* is more prevalent there. Hall (1973) reports similar sites in the Blue Mountains of Oregon, although much of his description includes the upper portion of our *ABLA/CAGE* h.t.

Pinus albicaulis Series



Distribution. — *Pinus albicaulis* h.t.'s appear in the Challis and Open Northern Rockies sections but are more common in the Wind River Range of Wyoming and northward into Montana. The *P. albicaulis* h.t.'s extend downward from upper timberline on dry exposed ridges and on southerly to westerly aspects. At lower elevations or on cooler aspects they merge with *Abies lasiocarpa* or *Pinus contorta* communities.

Vegetation. — *Pinus albicaulis* is the dominant tree and is often deformed or stunted by wind, cold, or drought. Undergrowths vary considerably and range from a layer of *Festuca idahoensis* on very exposed sites (fig. 35) to *Carex geyeri* and *Vaccinium scoparium* on more moderate sites.

Productivity/Management. — These h.t.'s appear to have very low timber potential but may have high watershed values. Forage production may sustain light grazing but grazing abuse can easily decimate the forage and expose the soil. The vegetation recovers very slowly and, in some areas, soil loss can prevent complete restoration. These sites generally have low undergrowths that permit easy travel and the surrounding scenery has considerable esthetic appeal. Recreationists seek these areas for hiking and camping, but if concentrated, these activities can easily disrupt soils and vegetation.

Other studies. — Some people have delineated h.t.'s within the *PIAL* series. Cooper (1975) and Reed (1976) discuss a *Pinus albicaulis/Vaccinium scoparium* h.t. in western Wyoming. This h.t. also extends into Montana (Pfister and others 1977; Weaver and Dale 1974) and occupies the moister portions of the *Pinus albicaulis* zone. Cooper (1975) describes a *Pinus albicaulis/Carex geyeri* h.t. that represents small topoedaphic conditions in western Wyoming and adjacent Idaho. Some sites that are very exposed to wind and sun support a *Pinus albicaulis/Festuca idahoensis* community. This condition appears in the Wind River Range of Wyoming (Steele and others 1979, unpubl. ref.) and in Montana (Pfister and others 1977) as well as in central Idaho.

The above studies suggest that there is considerable diversity within the *Pinus albicaulis* series. Until we obtain more data from these difficult-access areas we prefer not to subdivide h.t.'s within the *Pinus albicaulis* series for central Idaho. However, all of these conditions have generally low productivity values and can be treated collectively as *Pinus albicaulis* h.t.'s for the practicalities of management.

Pinus contorta Series

Distribution. — This series consists of pure stands of *Pinus contorta* that contain little evidence that any other tree species is climax. Environmentally it is similar to colder portions of the *Pseudotsuga* series and drier parts of the *Abies lasiocarpa* series. Theoretically it may occur wherever *P. contorta* can dominate the site, but mostly it appears on the gentle terrain of benches, toe-slopes, and valley bottoms.

Figure 35. — A Pinus albicaulis *h.t. on a westerly exposure in the Lemhi Mountains south of Gilmore, Idaho (9,400 feet [2 870 m] elevation). A few* Abies lasiocarpa *appear in the swale, but only* Pinus albicaulis *occupies the slopes and is regenerating successfully.* Festuca idahoensis *dominates the undisturbed undergrowth in the foreground.*

Vegetation/Ecology. — In all cases *P. contorta* acts as the pioneer conifer, but its ability to remain dominant appears related to topoedaphic factors (Pfister and Daubenmire 1975). In central Idaho it tends to be more persistent on gentle terrain than on steep slopes. In some broad, high-elevation valleys it persists for many generations with little or no evidence of replacement by other conifers. Upper limits of these persistent *P. contorta* stands often resemble a contour, which suggests a response to impoundment of cold air or possibly storage of subsurface water. Slopes above these valleys have intermediate situations where *P. contorta* persists but is gradually replaced by *Abies lasiocarpa, Pseudotsuga*, or both. *P. contorta* also dominates some gentle slopes and benches near upper timberline, occasionally accompanied by minor amounts of *Pinus albicaulis.*

Pinus contorta is well adapted to cold-air drainages as evidenced by its ability to invade sites near receding glaciers (Heuser 1969). Over millenia, *P. contorta* seedlings have periodically invaded raw substrates of glacial alluvium and were subjected to intense daily insolation and nightly cold air accumulation and frost. Today, *P. contorta* still dominates glacial deposits of valley floors in Idaho and Wyoming in spite of other coniferous seed sources on adjacent uplands. Although *Abies lasiocarpa* and *Picea engelmannii* extend to upper timberline and easily replace *P. contorta* on steeper slopes, their tolerance to daily temperature extremes on these gentle valley floors appears less than that of *P. contorta.*

Fluctuating water tables may also contribute to the success of *P. contorta.* In central Idaho, many valleys where *P. contorta* now dominates were formed by fault block tectonics and later accumulated glacial outwash. The outwash apparently serves as an aquifer that is recharged by spring snowmelt but becomes very dry near the surface by late summer. Thus tree roots on these sites must endure a substrate that changes from waterlogged to droughty during the growing season. Tarrant (1953) summarized several studies that show *P. contorta* to be well adapted to coarse-textured soils

with intermittent high water tables. Stephens (1966) reports *P. contorta* to be well adapted to very poorly drained, and very well drained, glacial tills. In our area it is possible that high-water periods, or summer frost, prevent invasion of *Pseudotsuga* and the drought from low water periods excludes *Picea* and *Abies*.

Fire. — Pure *P. contorta* stands have often been attributed to repeated fire and in some areas this is the case. Yet fire is a minor factor in the most persistent stands in central Idaho. Undergrowths in these valley-bottom stands are generally sparse and produce little fuel. Most of the fuel occurs on adjacent slopes and natural fires on the valley floor that did not ascend these slopes would be very unusual. Yet quite often only the valley bottom contains pure *P. contorta* and adjacent slopes are in advanced stages of succession to *Abies* and *Pseudotsuga*. Also, upper limits of the persistent *P. contorta* stands often resemble a contour rather than previous patterns of fire. Furthermore, most *P. contorta* cones in central Idaho are nonserotinous. Thus, in these areas there is little evidence for fire maintenance of stable *P. contorta* stands. In fact, those stands that appear to be most stable have the widest spaced trees, the least undergrowth, and the gentlest slopes — all of which are unfavorable to fire spread.

Productivity/Management. — Timber potentials should be low to moderate in most of this series. From a practical standpoint, these sites can be managed as if *Pinus contorta* were climax even though *Pseudotsuga* or *Abies* may eventually invade the stand.

Deer and elk may use these sites for cover and escape. These communities may have other values to wildlife or livestock, depending on the type of undergrowth that is present.

Most of these sites have gentle terrain which provides easy access and development for recreation facilities. However, the recreationist may prefer areas that receive less frost and have a less monotonous appearance.

The community types (c.t.'s) in this series represent situations in which *Pinus contorta* is the only conifer on the site. On some h.t.'s this situation occurs only in initial stages of secondary succession and indications of the climax community soon become evident. On other sites, climax indicators invade more slowly. Here, determining habitat type is more tenuous and often requires some interpretation following investigation of the site and adjacent sites. However, such conditions can also be handled within this classification.

If the indicator species are present in the undergrowth, the stands can be assigned to the proper *Abies* or *Pseudotsuga* h.t. by using the key to *Pinus contorta* communities. Other sites where climax status for *P. contorta* is suspect can be treated as c.t.'s and managed as if *P. contorta* were climax. Although several conditions on gentle terrain are suspected to support *P. contorta* climax, only the *PICO/FEID* h.t. was found to consistently maintain *P. contorta* as the climax dominant.

Other studies. — In Montana, Pfister and others (1977) describe a *Pinus contorta* series in a similar manner. They note four community types and a *Pinus contorta/Purshia tridentata* h.t. near West Yellowstone. Cooper (1975) also describes this h.t. from the same area as occurring on very gentle terrain and receiving frequent summer frost. The substrate is obsidian sand underlain with lake silt. In Wyoming, Hoffman and Alexander (1976) describe *P. contorta/Arctostaphylos uva-ursi* and *P. contorta/Vaccinium scoparium* h.t.'s in the Bighorn Mountains and Reed (1976) notes a *P. contorta/Poa nervosa* h.t. in the Wind River Mountains. In south-central Oregon, Franklin and Dryness (1973) describe climax stands of *P. contorta* on pumice soils. These stands occur on nearly level areas in enclosed depressions that impound cold air at night. On the Colorado Front Range, Moir (1969) recognized a stable zone of *P. contorta* that occurs mainly on gentle undulating terrain rather than canyon topography.

These studies collectively demonstrate that *P. contorta* can remain dominant on gentle terrain for many generations. The governing factors on these sites appear to be nightly cold air accumulation, with frequent summer frost and droughty substrates, perhaps with fluctuating water tables. On these sites, *P. contorta* remains dominant because other conifers are unable to grow there, not superiority in interspecific competition. These studies also show that although *P. contorta* typically forms seral stands that persist to varying degrees, in some parts of its environmental spectrum it does form climax stands.

PINUS CONTORTA/VACCINIUM CAESPITOSUM COMMUNITY TYPE (*PICO/VACA* C.T.; LODGEPOLE PINE/DWARF HUCKLEBERRY)

Distribution — The *PICO/VACA* c.t. occurs most often in the higher valleys of the Southern Batholith section. Here it occupies the gentle to undulating terrain of glacial outwash and adjacent toe-slopes near lower elevations of the *Abies lasiocarpa* zone. Most sites apparently accumulate considerable cold air at night and severe frost is not uncommon throughout the summer.

Vegetation/Ecology. — A layer of *Vaccinium caespitosum* is common in the undergrowth and is usually accompanied by *Calamagrostis rubescens*. Seral shrubs are normally scarce. All stands of the *PICO/VACA* c.t. observed to date appear closely related to the *ABLA/VACA* h.t., but occasional stands may represent the cold extreme of *PSME/VACA*. Usually, conifers other than *P. contorta* invade very sporadically and determination of the climax dominant can be very difficult.

Productivity/Management. — For timber production, all stands of the *PICO/VACA* c.t. can be managed as the *ABLA/VACA* h.t. (see p. 67).

Other studies. — Pfister and others (1977) also found a *PICO/VACA* c.t. in Montana. In central Oregon, Franklin and Dryness (1973) mention a *Pinus contorta/Vaccinium uliginosum* c.t. that contains *V. caespitosum* and resembles our *PICO/VACA* c.t.

PINUS CONTORTA/VACCINIUM SCOPARIUM COMMUNITY TYPE *(PICO/VASC* C.T.; LODGEPOLE PINE/GROUSE WHORTLEBERRY)

Distribution.— The *PICO/VASC* c.t. occurs mainly in the Southern Batholith and Salmon Uplands sections. It can also be found in the Open Northern Rockies section, especially in the Beaverhead Mountains, and in Montana, Wyoming, eastern Idaho, and eastern Oregon. It is found on a variety of slopes and aspects at mid- to upper elevations of the *Abies lasiocarpa* zone.

Vegetation/Ecology. — A low cover of *Vaccinium scoparium* usually dominates the undergrowth. Other shrubs, if present, are usually sparse and well scattered. A few forbs such as *Arnica, Lupinus,* and *Valeriana* are often present. *Pinus albicaulis* may be present in various amounts.

Most *PICO/VASC* c.t.'s occupy the *ABLA/VASC* h.t.; however, on gentle slopes and broad benches an occasional *PICO/VASC* c.t. may appear so persistent as to suggest a *P. contorta* climax.

Productivity/Management. — In all cases, *P. contorta* is the most suitable timber species and other management guidelines should follow those of the *ABLA/VASC* h.t. (see p. 74).

Other studies. — In Montana, Pfister and others (1977) describe a *PICO/VASC* c.t. that occurs near and east of the Continental Divide. Hoffman and Alexander (1976) describe a *PICO/VASC* h.t. in Wyoming's Bighorn Mountains that is very similar to our *PICO/VASC* c.t. This c.t. is also described in eastern Idaho and western Wyoming (Steele and others 1979, unpubl. ref.), and in eastern Oregon (Hall 1973).

PINUS CONTORTA/CAREX GEYERI COMMUNITY TYPE *(PICO/CAGE* C.T.; LODGEPOLE PINE/ELK SEDGE)

Distribution.— The *PICO/CAGE* c.t. is most common on granitic soils of the Southern Batholith section, but may also occur in other areas. It usually occupies the cool, dry aspects of relatively gentle terrain and is common in the broad high valleys of central Idaho near lower elevations of the *Abies lasiocarpa* zone.

Vegetation/Ecology. — Normally *Carex geyeri* dominates a depauperate undergrowth that contains only a few forbs. Shrubs are seldom conspicuous.

Most stands of the *PICO/CAGE* c.t. apparently occupy the *ABLA/CAGE* h.t. A few may also occur near the cool extremes of the *PSME/CAGE* h.t. An occasional stand appears persistent enough to suggest that *P. contorta* is climax.

Productivity/Management. — Timber potentials should be low to moderate. In all cases, *Pinus contorta* appears to be the most suitable timber species. Other management guidelines should follow those for the *ABLA/CAGE* h.t. (see p. 76).

Other studies. — This c.t. is also mentioned in western Wyoming and eastern Idaho (Steele and others 1979, unpubl. ref.)

PINUS CONTORTA/FESTUCA IDAHOENSIS H.T. *(PICO/FEID;* LODGEPOLE PINE/IDAHO FESCUE)

Distribution.— The *PICO/FEID* h.t. is best represented in the Southern Batholith section. Small amounts also appear in the Challis, Salmon Uplands, and Open Northern Rockies sections. It ranges from 5,200 to 7,500 feet (1 590 to 2 286 m) and tends to occur at mid- to lower elevations of the subalpine zone but may occur up to 9,000 feet (2 746 m) on broad, gentle ridges. It is usually restricted to very gentle terrain on glacial moraines, outwash, and terrace lands. On the same landform, this h.t. often borders the *ABLA/VACA* h.t. on more mesic sites and *Artemisia/Festuca* communities on drier sites. Adjacent slopes and benches are usually the *ABLA/CAGE* or *ABLA/CARU* h.t. dominated by persistent stands of *Pinus contorta.*

Vegetation.— *Pinus contorta* is usually the only tree present but *Pinus albicaulis* may occur here sporadically. *Festuca idahoensis* dominates a normally depauperate undergrowth which may have small amounts of *Carex rossii, Arenaria, Antennaria, Penstemon,* and occasionally *Calamagrostis rubescens* (fig. 36). *Artemisia* is also often present and may dominate when the tree canopy is removed.

In some areas, widely scattered *Pinus contorta* dominate a sparse undergrowth that is apparently too dry for *Festuca idahoensis.* Here *Stipa occidentalis* is

Figure 36. — Pinus contorta/Festuca idahoensis *h.t. on a broad flat in Landmark Valley northeast of Cascade, Idaho (6,720 feet [2 050 m] elevation). A pure, open stand of multi-age* Pinus contorta *dominates the site.* Festuca idahoensis *dominates a very depauperate undergrowth.*

dominant and probably represents a different environment. The small areas involved, however, preclude positive h.t. recognition and for most practical purposes can be included with the *PICO/FEID* h.t. However, a *Pinus contorta/Stipa occidentalis* h.t. is described in central Oregon (Franklin and Dyrness 1973).

Soil. — Soil parent materials are mostly quartz monzonite or granitics and occasionally andesite or quartzite. Textures vary from loam to sandy loam and are usually gravelly. The pH ranges from 5.0 to 5.9 and averages 5.4. Coverage of bare rock is usually less than 5 percent but areas of bare soil may reach 30 percent. Average litter depth on a site seldom exceeds 1 cm.

Productivity/Management. — Timber potential is usually low to very low (appendix E-2). Trees regenerate consistently, but their growth is slow and their natural spacing is often quite wide.

Forage production is usually low, but livestock use these sites for shelter and light grazing. In early spring when the soil is wet, cattle may uproot the small clumps of *Festuca* and thereby reduce forage yield and soil cover.

Browse for big game is nil but where this h.t. borders meadows, it is used for cover by elk, mule deer, red fox, and coyotes. These sites may also have some value for elk calving and provide perches for raptors that hunt adjacent meadows.

The gentle terrain of these sites provides easy access and development for recreation facilities, but recreationists may prefer more scenic diversity.

Other studies. — Schlatterer (1972, unpubl. ref.) first described *PICO/FEID* in central Idaho but no one has reported it from outside the study area. Similar situations with *Purshia* as the undergrowth dominant are described in south-central Montana (Pfister and others 1977) and central Oregon (Franklin and Dyrness 1973).

Other Vegetation Types

Although this classification covers the vast majority of forest land in central Idaho, several situations supporting trees are excluded.

JUNIPERUS OSTEOSPERMA COMMUNITIES

Juniperus osteosperma extends northward from the Great Basin into southern portions of the Lemhi and Lost River Ranges. Here it forms extensive woodlands on foothills overlooking the valley floor. Attempts to classify h.t.'s of the pinyon-juniper zone in the Great Basin may eventually include this outlying population of juniper.

PINUS FLEXILIS COMMUNITIES

Near Craters of the Moon National Monument, widely scattered *Pinus flexilis* grow on a raw substrate of lava. Undergrowth vegetation is practically nonexistent. The peculiarities of these stands appear unique in Idaho and may be broadly treated as a single unit. Small amounts of other undefined *P. flexilis* communities in our area may consolidate with future studies to the south and southeast.

FLOOD PLAIN COMMUNITIES

In central Idaho, a few of the larger rivers and streams form floodplains as they encounter more gentle terrain toward the steppe. Various proportions of *Populus, Betula, Salix, Crataegus,* and occasionally *Alnus* dominate a rank undergrowth of tall shrubs and lush forbs. Sometimes conifers are weakly represented. Fluctuations of stream activity may continually alter soil depths and water tables and cyclic floods can alter substrate composition. The frequent interruption of succession and substrate alterations present unique difficulties in applying the potential climax concept that is commonly used for habitat type classification of more stable sites.

POPULUS TREMULOIDES COMMUNITIES

Populus tremuloides dominates a variety of sites within the study area. Its successional role varies from a rapidly seral species to persistently seral and even climax. The most apparent climax conditions are those stands that occur beyond the lower limits of conifers. These stands tend to occupy the concave slopes of low hills. Small amounts of this condition appear in foothills bordering the Camas Prairie and Snake River Plain in Elmore, Camas, and Blaine Counties. It becomes much more prevalent in southeastern Idaho and Utah where classification of these communities is in progress.

GRASS AND SHRUB COMMUNITIES

Grass and shrub communities are interspersed throughout much of central Idaho's forest. Schlatterer (1972, unpubl. ref.) has described many of these conditions in the Sawtooth, White Cloud, Boulder, and Pioneer Mountains. Mueggler and Harris (1960) offer some stratification to the mountain grasslands. Some classifications from adjacent areas may also be applied to portions of central Idaho. Daubenmire's (1970) classification of grasslands in Washington may apply to the extreme northwestern part of our area, and Hall's (1973) work in eastern Oregon may be helpful in our Weiser River drainage. A classification of grasslands and shrublands in Montana (Mueggler and Handl 1974, unpubl. ref.; Mueggler and Stewart 1980) should apply to adjacent portions of east-central Idaho. A current study of communities in southern Idaho (Hironaka 1977, unpubl. ref.) will also apply to southern portions of our area.

INDIVIDUAL ATTRIBUTES OF HABITAT TYPES

Soils

Characteristics of the upper 10 cm of soil are summarized in appendix D-1 and as a paragraph in each habitat type description. Soil samples and rock samples were first examined in the laboratory by a soil scientist (George Wendt, Richard Thompson, Norm Bare, or Laverne Nelson; USDA Forest Service) to determine the textural class and parent material. Air-dry samples were then weighed, sieved (2 mm) to separate the gravel, and reweighed to determine percent gravel content. The soil separate was tested for pH with a glass-electrode pH meter in a 12-hour water paste solution.

Soil sampling and analyses were designed to obtain a simple characterization of surface soils for each habitat type, rather than detailed soil-vegetation relationships. Even our limited data (appendix D-1) make it evident that some habitat types are strongly controlled by edaphic or topoedaphic factors and have a narrow range of soil characteristics. The *PIFL/FEID* and *PIEN/HYRE* h.t.'s show a strong affinity for calcareous substrates. Several habitat types such as *PIEN/CADI, ABLA/CACA, ABLA/CABI,* and *ABLA/STAM* occur where water tables are close to the surface at least part of the year. Other habitat types such as *PSME/CARU, ABLA/CARU,* and *ABLA/VASC* occur on a broad range of soils. There is also a tendency for some of the wet-site habitat types to have the greatest litter accumulations and least exposed soil and rock. In contrast, the most severe habitat types have the least litter and greatest areas of exposed soil and rock.

It is often theorized that vegetation or habitat types can be predicted from soil characteristics. But R. and J. Daubenmire (1968) have emphasized that correlation between habitat types and soil types (classified on the basis of standard soil profile characteristics) is too weak to allow prediction of habitat types from soil types, or vice versa. We support this viewpoint as a general rule for several reasons. First, the development of a soil profile reflects a long-term integration of soil forming factors, whereas vegetation development is much more sensitive to current climatic conditions. Second, soil classification systems are not designed to primarily reflect influences on vegetational development; therefore, predictive capabilities should not necessarily be expected. Third, vegetational development depends on many factors, of which soil characteristics is only one. According to the principle of factor interaction, plants are able to grow on a wide range of substrates when other factors provide compensatory effects.

Land managers should be cautious about attempting to "shortcut" inventories of either vegetative potentials or soils through the process of "assumed correlations". Some useful correlations undoubtedly exist; but they must be developed objectively, tested adequately, and extrapolated with caution.

Climate

Appendix D-2 shows climatic patterns that represent various habitat types and phases. Most of the data are from U.S. Weather Service stations. The habitat type and phase shown for each station is an estimation of the appropriate climatic climax.

Other climatic data representing specific forest habitat types may be available from Weather Service records or special studies made by various researchers. However, careful evaluation of the site is necessary to determine the appropriate climatic climax. For instance, climatic data from a site supporting an edaphic climax should be interpreted in relation to the nearest expression of a climatic climax, rather than the immediate edaphic climax.

Vegetation

ECOLOGIC ROLES OF PLANT SPECIES

Most plant species are distributed independently along environmental gradients. However, many species express different ecologic roles in different segments of their distribution. A single species can be either dominant or subordinant, and either climax or seral in different environments. Thus a species value as an ecologic indicator depends on its position along the gradient being considered and the relative position of its associates. Relative ecologic expressions of important species in central Idaho forests are presented in several ways.

The occurrence and roles of tree species (appendix B) reflects the relative amplitude and successional status of our tree species in the various h.t.'s and phases. This chart provides some of the basic information needed to select and manage the tree species best adapted to a given segment of the forest environment.

For instance, *Pinus ponderosa* is a major seral species in some *Abies grandis* and *Pseudotsuga* habitat types but is climax in the *Pinus ponderosa* series. Furthermore, *P. ponderosa* reaches highest site index values (appendix E-1; Daubenmire 1961) in *Abies grandis* habitat types where it is a rapidly replaced seral species, intermediate site indexes in the *Pseudotsuga* series where it is a more persistent seral species, and lowest site indexes in the *Pinus ponderosa* series where it is climax. Generally, species with both climax and seral occurrence attain their maximum growth rates on some sites where they are seral. In addition, seral species are also usually easier to regenerate following disturbance than the climax species. However, in determining application of these generalities to specific sites and species, the user is cautioned to check the appropriate appendix tables and other available information.

When relative height growth rates are compared (appendix E-1), it is apparent that in many h.t.'s at least one of the seral species tends to grow faster than the climax species. One notable exception, however, is the *Abies grandis* x *A. concolor* hybrids that have greater height growth rates than *Pinus ponderosa* in some *Abies grandis* habitat types. This anomaly is found in our Wallowa-Seven Devils section and is also reported in eastern Oregon (Hall 1973). However, the question of hybrid vigor arises and we do not yet know if the *Abies* that can outproduce *P. ponderosa* in seral stands is the same genotype that dominates at climax.

The constancy and average coverage data (appendix C) portray the relative amplitude of major forest species and degree of dominance through the spectrum of forest habitat types. Comparison of habitat types using these data from mature stands provides insight to the habitat type classification that is not available in the keys or written descriptions. These tables also condense the vegetal information of each habitat type and reduce the need for elaborate vegetative descriptions.

For instance, *Lonicera caerulea* is relatively uncommon in central Idaho, yet it occurs in 80 percent of the stands sampled in the *ABLA/CACA* h.t., *VACA* phase. Also, it has an average coverage of 4 percent in those stands where it occurs, but it has an ecologic amplitude of only five different habitat types or phases.

Using appendix C, it is also possible to contrast differences between habitat types or phases. For instance, the difference between the *PIPO* and *SPBE* phases of *PSME/SPBE* (appendix C) is more than the ability to produce *Pinus ponderosa*. The *PIPO* phase can also support *Ceanothus velutinus, Salix scouleriana,* and *Penstemon wilcoxii,* none of which are listed for the *SPBE* phase.

TIMBER PRODUCTIVITY

Timber productivity is one of the key management implications for which data were collected during this study. Site trees were selected to determine the potential height growth of relatively free-growing trees. One site tree of each species was selected for each stand wherever possible. Site trees showing marked suppression of diameter growth (diameter growth during a 30-year period less than growth during any subsequent 10-year period) were rejected during analysis of the increment cores. Diameter growth suppression of 10- and occasionally 20-year periods were not uncommon in the site trees remaining for productivity analyses. Old-growth and stagnated trees were not used for productivity estimation. Even though only a single site tree per species per stand was used, the data are reasonably consistent. Comparisons appear to be valid, and the large number of sample sites (541 stands) permits comparison of productivity among habitat types as well as variability within each habitat type.

Determination of site index from height-age data requires specific procedures for each tree species. The number of years to reach breast height (4.5 feet [1.4m]) must be measured or estimated for species having height-total age site curves. If a site curve is not available, a curve from another species must be substituted. Criteria used to determine total age, as well as sources of site index curves and yield capability data for this analysis, are summarized in table 3.

We used *Pinus ponderosa* curves for determining *Pseudotsuga* site index rather than Brickell's (1968) *Pseudotsuga* curves because the curve shapes for *Pinus ponderosa* are more realistic for our data (giving closer estimates for different-aged site trees in the same stand). Furthermore, because *Pinus ponderosa* yield tables are currently used to estimate *Pseudotsuga* yields in the Northern Rocky Mountains, it is more logical to use the *Pinus ponderosa* site index curves for *Pseudotsuga* height-age data.

We used Alexander's (1967) *Picea engelmannii* curves rather than Brickell's (1966) because: (1) Alexander's are based on breast-height age (data available) rather than total age (estimate required); (2) the curve shapes are more realistic for our data (giving closer estimates for different-aged site trees in the same stand); and (3) yield data related to the curves are available (Alexander and others 1975). We also used Alexander's (1967) *Picea engelmannii* curves for *Abies lasiocarpa,* for which there are no site index curves available.

The site index data (base age 50 years) have been summarized by species within habitat types (appendix E-2). The mean site index was calculated whenever three or more values were available. With five or more values, a 95-percent confidence interval for estimation of the true population mean was calculated. (The confidence interval narrows with both decreased variability and increased sample size.) The same procedure was used for summarizing basal areas of sample stands.

Although site productivity can be compared by using site index alone, a more useful comparison can be made by using the estimated net yield capability of the site (cubic-volume production). Until managed-stand yield tables are completed, the best approach is to use natural-stand yield tables for assessing yield capability. As stated by Brickell (1970), "Yield capability, as used by Forest Survey, is defined as mean annual increment of growing stock attainable in fully stocked natural stands at the age of culmination of mean annual increment." (In other words, yield capability = maximum mean annual increment attainable in fully stocked natural stands. For additional explanation see Glossary, appendix G.)

The curves used to estimate yield capability from site index are presented in figure 37.

Yield capability values are based on cubic feet of all trees (>0.5 inch d.b.h.). The *Larix occidentalis* curve was derived from Schmidt and others (1976). (Brickell's [1970] curve for this species was only for trees greater

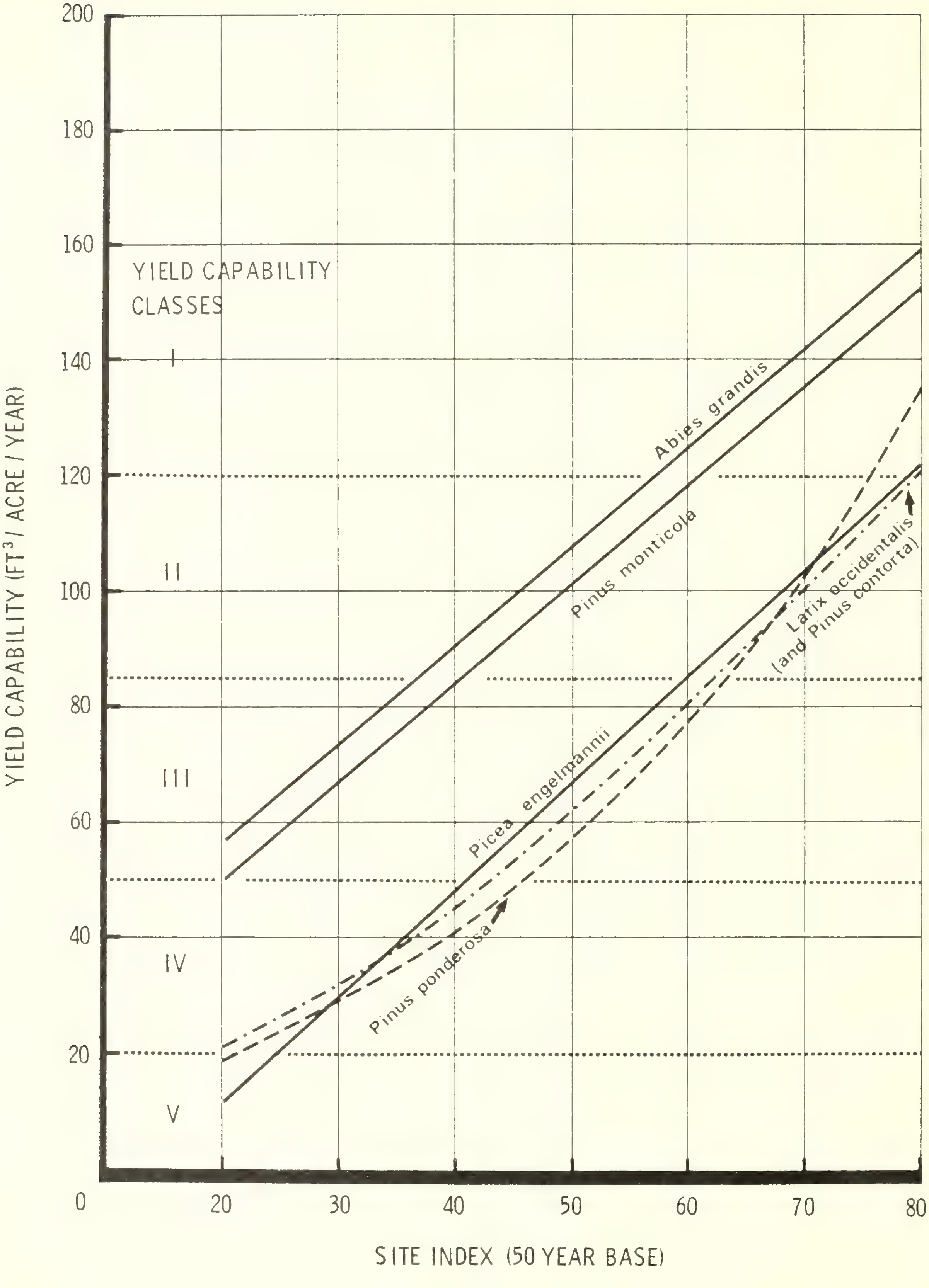


Figure 37. — Yield capability of fully stocked natural stands in relation to site index (from Pfister and others 1977).

Table 3.--Criteria and sources for determining site index and for estimating yield capability

Species	Estimated years to obtain breast height	Source of site curve[1]	Yield capability (all trees - fig. 37)
PIPO	10	Lynch 1958	Brickell 1970
PSME	10	Used PIPO curves	
PICO	10	Alexander 1966	Used LAOC curve[2]
LAOC	5	Schmidt and others 1976	Schmidt and others 1976[2]
PIEN	([3])	Alexander 1967	Alexander[4]
ABGR	([3])	Stage 1959	Brickell 1970
ABLA	([3])	Used PIEN curves	

[1] All site curves with a 100-year index age were converted to a 50-year index age.

[2] Brickell's (1970) curves for PICO and LAOC (trees larger than 5.0 inches) were nearly identical. A new curve (based on all trees) was developed for LAOC from yield data in Schmidt and others (1976). The LAOC curve for all trees appears to be as accurate as any available for estimating PICO yield capability for all trees.

[3] Curves based on age at breast height were used.

[4] Data used in a recent yield study (Alexander and others 1975) were provided by Alexander. Site index and mean annual increment from 21 fully stocked natural stands were used to develop the curve shown in figure 37. (Yield capability = 26.0 + 1.84 Site Index (50; R^2 - 0.66.)

than 5.0 inches in diameter.) The *Larix* curve was also used for *Pinus contorta* because Brickell's (1970) curves (trees >5.0 inches) are almost identical for the two species, and because natural-stand yield data have not been published for *Pinus contorta*.

The *Picea* curve was derived from original data used in developing managed-stand yield tables (Alexander and others 1975). We calculated mean annual increment for all trees for 21 of Alexander's fully stocked natural stands near the age of culmination of mean annual increment (ages from 97 to 165 years). A linear regression of yield capability on Alexander's (1967) site index was conducted, converted to site index at base-age 50, and plotted in figure 37. (Yield capability = -26.0 + (1.84 x 50-year site index), $R^2 = 0.66$.) The other curves were developed by Brickell (1970) from natural-stand yield tables.

The large spread in site index-yield capability curves (fig. 37) illustrates the importance of using species-specific curves for estimating productivity. We suspect that the *Abies grandis* curve (developed in northern Idaho) may be incorrectly estimating yield capabilities for central Idaho. However, we did not have central Idaho yield data to test the relationship.

Our best current estimates of yield capability (in cubic feet/acre/year) for each habitat type are shown in appendix E-2. Procedures used to develop these estimates were:

1. Yield capability was estimated for each site tree from appropriate species curves according to the criteria in table 3. These values were plotted by habitat type and phase for a visual display of distribution.

2. Adjusted yield capability figures were developed for those habitat types where stockability appears to limit productivity. Basal area data for plots in these types were compared with Meyer's (1938) basal area data for fully stocked "normal" stands, following the approach of MacLean and Bolsinger (1973). This ratio was multiplied by yield capability for a given site index to determine the adjusted yield capability for each site tree.

3. Mean yield capability (or adjusted yield capability) for all site trees in each habitat type was calculated and cutoff points were established to approximate 90 percent of the range of our data. Only those types with a minimum of five sample stands are shown in appendix E-2. A mean stockability factor is shown for those types where yield capabilities were adjusted.

These current best estimates (appendix E-2) portray both relative productivity of habitat types and the range of productivity within a habitat type. From these, it is possible to assign a ranking or qualitative rating of potential timber productivity of natural stands for use in planning.

As Daubenmire (1976) emphasized, natural vegetation serves as a convenient indicator of productivity over large areas of land. However, productivity within habitat types (appendix E) often varies substantially. Reasons for this variability and suggestions for reducing it are as follows:

1. Site-index curves were used to obtain productivity data from yield tables. Different height-growth patterns undoubtedly occur in different habitat types, but data to account for this variation are not available.

2. Yield tables and site curves have not been developed for all species, making extrapolation necessary.

3. Yields of mixed species stands can be estimated by several individual species' yield tables. We found that a range of 30 to 40 cubic feet/acre/year in yield capability was common in individual stands, depending upon the species used for estimation. The *Abies grandis* types show an unusually wide range in productivity because of relatively high site index values (appendix E-1) coupled with the high yield capability/site ratio (fig. 37).

4. Some variability in productivity within a habitat type is to be expected within a natural classification system. The habitat type classification is based on abilities of species to reproduce and mature under competition, not on their rates of growth. The correlation between this and productivity is imperfect. (For instance, in some stands tree roots draw on underground water tables and achieve excellent growth rates, while surface drought limits establishment of tree seedlings and undergrowth.)

5. Where a more accurate estimate of productivity is needed for local areas, we recommend taking additional site-index samples.

6. It has been suggested that productivity estimates for habitat types could be improved by incorporating classifications of soils, topography, or climate. Differences in productivity within a habitat type due to topography or soils are apparent in some local areas. However, because of the limitations of existing site index curves and yield tables, further refinement of productivity estimates will likely require additional data and more accurate methods of estimating productivity. For instance, natural-stand yield capability could be estimated more precisely by direct measurements of volume growth, rather than by using site index to enter a yield table based on averages. This would require analysis of those existing timber inventory plots representing maximum growth potential and probably additional field measurements.

7. Recent stand growth models (Stage 1973, 1975) utilize growth coefficients based on habitat types. These add a new dimension to yield prediction, provide the basis for developing managed-stand yield tables, and should improve our knowledge of productivity within and between habitat types.

Zonal Relationships of Habitat Types

Just as individual species occur in a predictable sequence with changing environments, h.t.'s also display predictable patterns in local areas. On a larger scale, the sequence of h.t.'s will vary through additions or omissions but their relative positions should remain constant. Thus *Pseudotsuga* h.t.'s normally occur in warmer and drier environments than *Abies lasiocarpa* h.t.'s, but *Abies grandis* h.t.'s may occur between the two series or may be absent. This rule applies to patterns of individual h.t.'s and phases as well as series.

In order to demonstrate the relative positions of central Idaho h.t.'s, schematic diagrams (figs. 38-45) are presented for characteristic localities of each physiographic section. These diagrams are frustrated by the difficulty of depicting a three-dimensional landscape in two dimensions, and so are not literally accurate. Also, the number of h.t.'s in any given transect may vary from the general diagram for that particular area. Nevertheless, they do present a generalized concept of habitat type zonation in different geographical areas.

Relationship to Previous Habitat Type Classifications in Idaho

As in any classification procedure, increased accuracy is obtained through a series of approximations, with each step adding refinement. This classification suggests several possible refinements to the pioneering work of R. and J. Daubenmire (1968) in northern Idaho although it is by no means intended to cover that area. It also represents a few revisions to the preliminary classifications for central Idaho (Pfister and others 1973, unpubl. ref.; Steele and others 1974, unpubl. ref.). Figure 46 illustrates the relationships of these classifications in terms of the variation encompassed by each h.t. and phase.

Figures 38-45. — Schematic relationships of trees and key undergrowth species that could be encountered with increasing elevation in mature forest stands. Length and position of horizontal bars portray relative occurrences of species along a climatic gradient. Heavy lines indicate that climatic gradient. Heavy lines indicate that portion of a species environmental range where it is used to designate a habitat type.

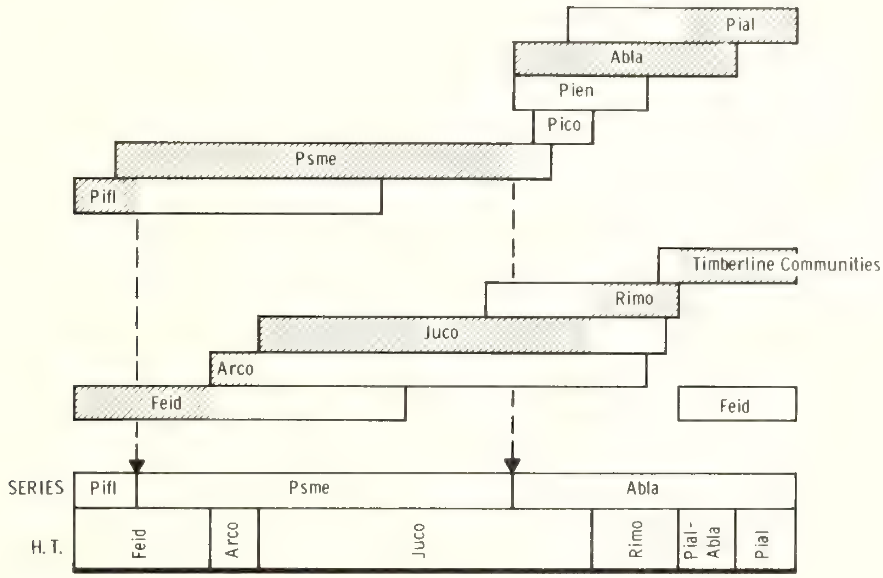


Figure 38. — General relationships of forest vegetation in the open Northern Rockies section near Gilmore, Idaho.

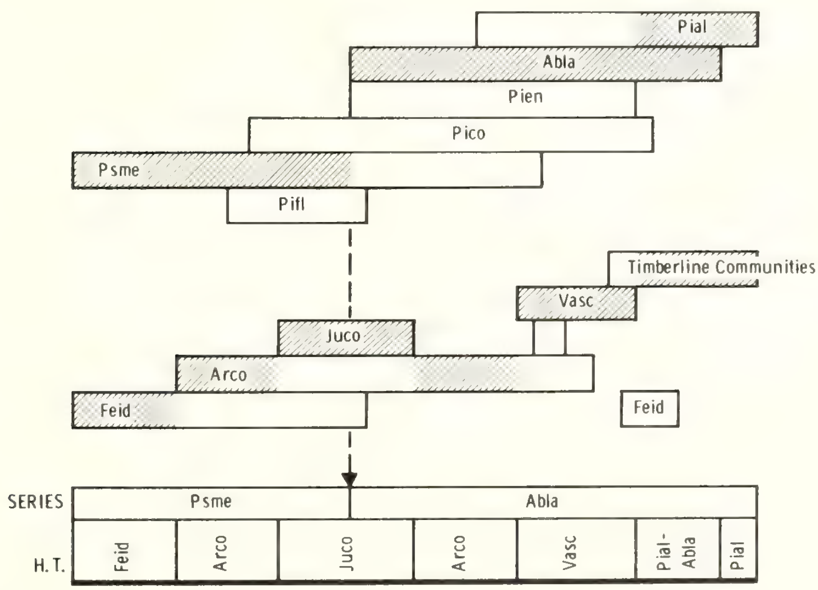


Figure 39. — General relationships of forest vegetation in the Challis section near Challis, Idaho.

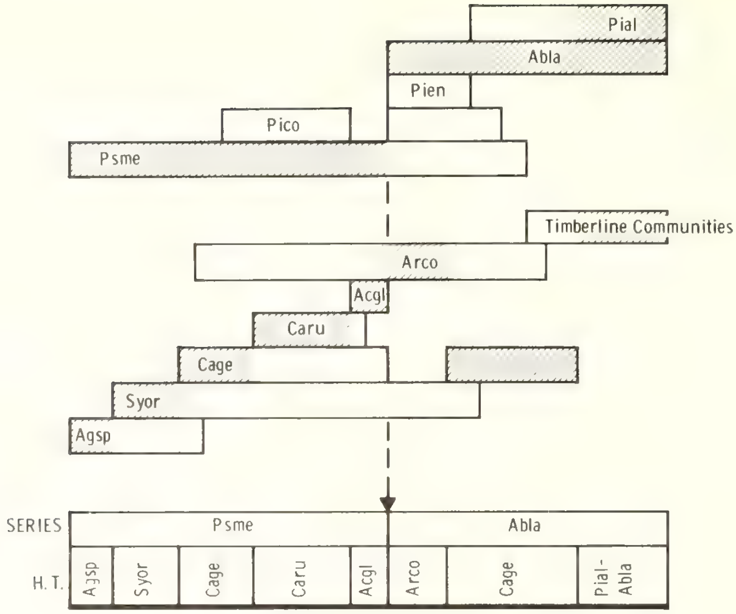


Figure 40. — General relationships of forest vegetation in the Challis section near Ketchum, Idaho.

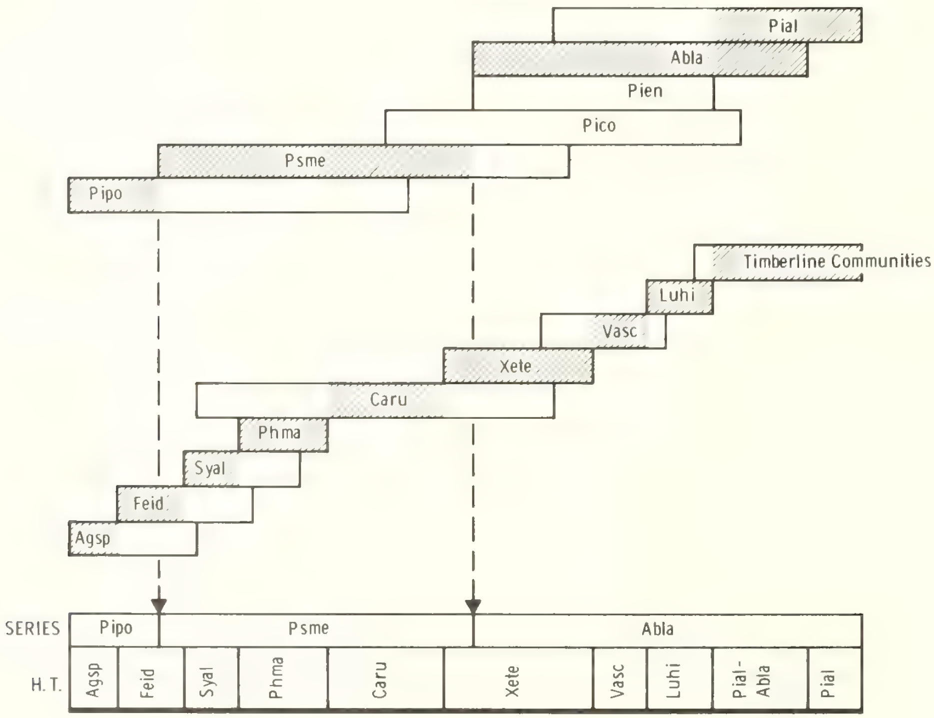


Figure 41. — General relationships of forest vegetation in the Salmon Uplands section near Shoup, Idaho.

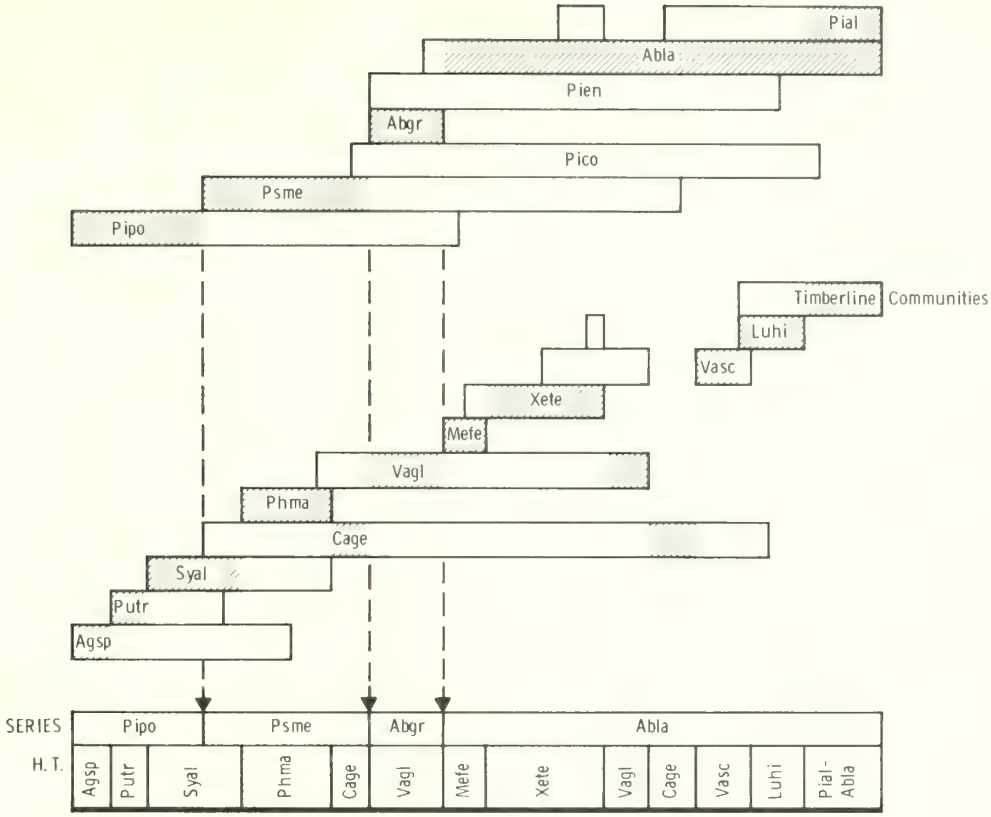


Figure 42. — General relationships of forest vegetation in the Salmon Uplands section near Warren, Idaho.

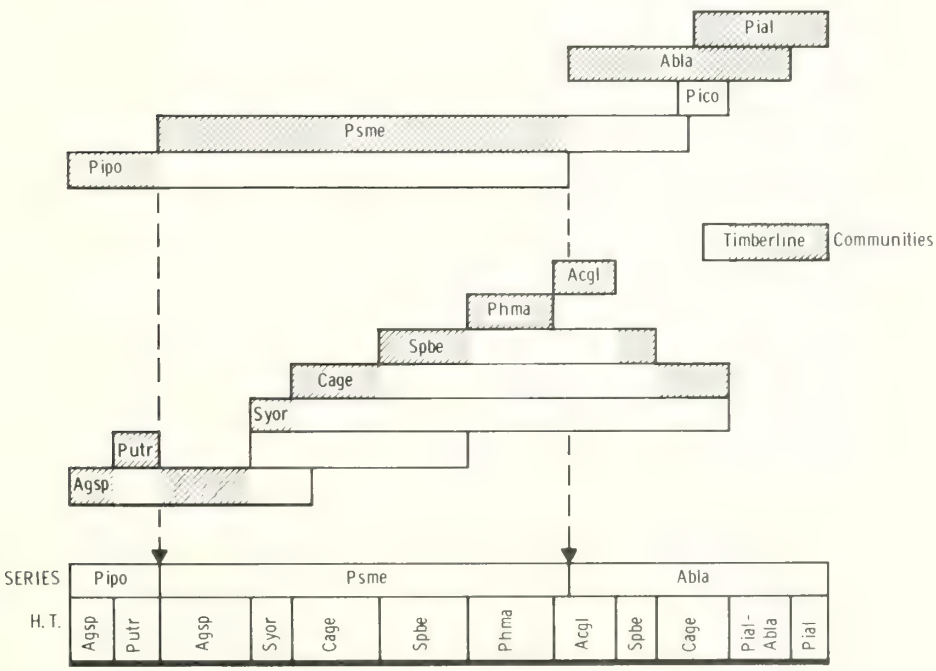


Figure 43. — General relationships of forest vegetation in the Southern Batholith section near Featherville, Idaho.

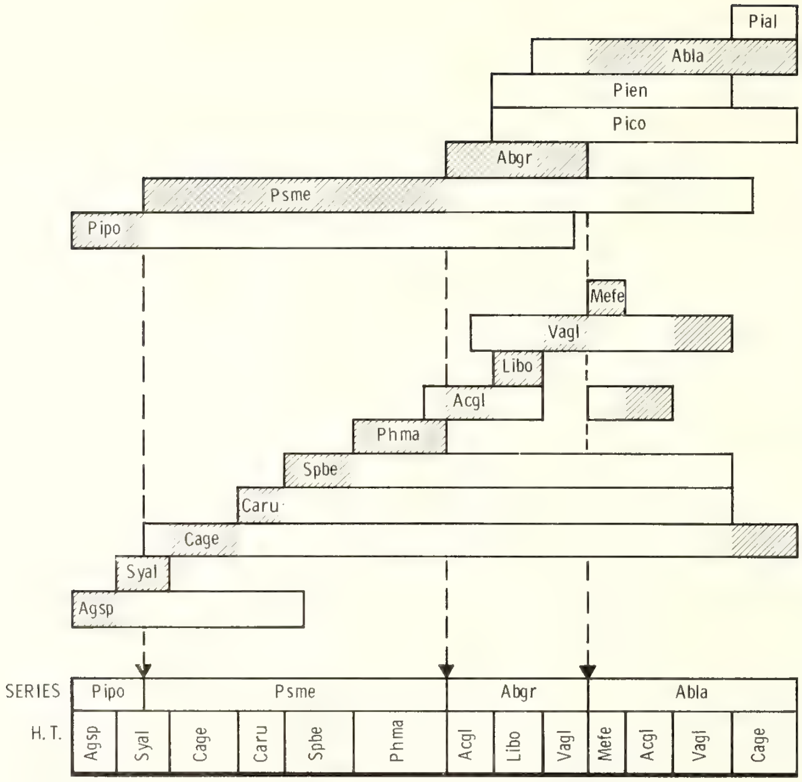


Figure 44. — General relationships of forest vegetation in the Southern Batholith section north of Crouch, Idaho.

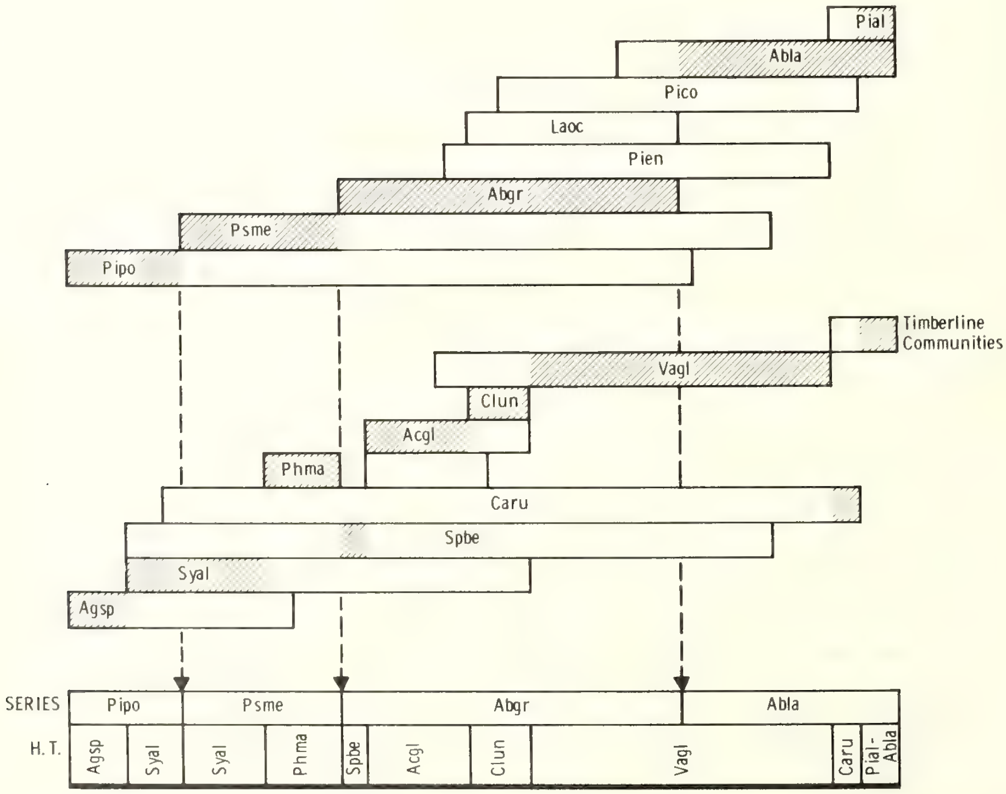


Figure 45. — General relationships of forest vegetation in the Wallowa-Seven Devils section near Council, Idaho.

NORTHERN IDAHO & EASTERN WASH. R & J DAUBENMIRE 1968	BOISE & PAYETTE N.F. PFISTER & OTHERS 1973	CHALLIS, SALMON, & SAWTOOTH N.F. STEELE & OTHERS 1974	CENTRAL IDAHO REVIEW DRAFT STEELE & OTHERS 1975	CENTRAL IDAHO H.T.S.
PIPO/ STCO				
			PIPO/ STOC	PIPO/ STOC
PIPO/ AGSP	PIPO/ AGSP	PIPO/ AGSP	PIPO/ AGSP	PIPO/ AGSP
PIPO/ FEID	PIPO/ FEID	PIPO/ FEID	PIPO/ FEID	PIPO/ FEID
			PIPO/ PUTR AGSP	PIPO/ PUTR AGSP
PIPO/ PUTR	PIPO/ PUTR	PIPO/ PUTR	PIPO/ PUTR FEID	PIPO/ PUTR FEID
	PIPO/ PRVI		PIPO/ SYOR	PIPO/ SYOR
PIPO/ SYAL	PIPO/ SYAL	PIPO/ SYAL	PIPO/ SYAL	PIPO/ SYAL
PIPO/ PHMA	PIPO/ PHMA		PIPO/ PHMA	PIPO/ PHMA
		PIFL/ FEID	PIFL/ FEID	PIFL/ FEID
	PSME/ AGSP	PSME/ AGSP	PSME/ AGSP	PSME/ AGSP
	PSME/ SYOR (IN PART)	PSME/ SYOR SYOR	PSME/ SYOR SYOR	PSME/ SYOR
	PSME/ PRVI (IN PART)	PSME/ SYOR PRVI	PSME/ SYOR PRVI	
	PSME/ FEID	PSME/ FEID	PSME/ FEID	PSME/ FEID FEID PIPO
		PSME/ CELE	PSME/ CELE	PSME/ CELE
		PSME/ ARCO	PSME/ ARCO	PSME/ ARCO ASMI ARCO
		PSME/ OSCH	PSME/ OSCH	PSME/ OSCH
		PSME/ JUCO	PSME/ JUCO	PSME/ JUCO
				PSME/ BERE SYOR CAGE BERE
	PSME/ SYOR (IN PART) PSME/ PRVI (IN PART)	PSME/ CAGE SYOR	PSME/ CAGE SYOR	PSME/ CAGE SYOR
	PSME/ CAGE ARTR	PSME/ CAGE ARTR	PSME/ CAGE ARTR	
	PSME/ CAGE CAGE	PSME/ CAGE CAGE	PSME/ CAGE CAGE	PSME/ CAGE PIPO CAGE
PSME/ CARU CARU	PSME/ SYOR (IN PART) PSME/ PRVI (IN PART) PSME/ CARU	PSME/ CARU SYOR PSME/ CARU CARU PSME/ CARU ARUV	PSME/ CARU CARU PSME/ CARU ARUV	PSME/ CARU PIPO FEID CARU
PSME/ CARU ARUV				
	PSME/ SPBE CAGE	PSME/ SPBE CAGE	PSME/ SPBE CAGE	PSME/ SPBE PIPO CARU SPBE
	PSME/ SPBE CARU	PSME/ SPBE CARU	PSME/ SPBE CARU	
	PSME/ SPBE SPBE	PSME/ SPBE SPBE	PSME/ SPBE SPBE	
		PSME/ SYAL SYAL	PSME/ SYAL SYAL	PSME/ SYAL PIPO SYAL
PSME/ SYAL	PSME/ SYAL	PSME/ SYAL ARUV	PSME/ SYAL ARUV	
			PSME/ VAGL	PSME/ VAGL
	PSME/ ACGL	PSME/ ACGL	PSME/ ACGL	PSME/ ACGL SYOR ACGL
	PSME/ XETE	PSME/ XETE	PSME/ XETE	
			PSME/ PHMA ACGL	PSME/ PHMA PIPO PSME
PSME/ PHMA	PSME/ PHMA	PSME/ PHMA	PSME/ PHMA PHMA	
			PSME/ PHMA CARU	PSME/ PHMA CARU
				PSME/ LIBO
				PSME/ VACA
		PIEN/ CADI	PIEN/ CADI	PIEN/ EQAR PIEN/ CADI
		UNCLASSIFIED COMMUNITIES	UNCLASSIFIED COMMUNITIES	PIEN/ GATR
				PIEN/ HYRE

Figure 46. — Relationships of central Idaho habitat types to previous classifications in Idaho.

con

Figure 46. — con

NORTHERN IDAHO & EASTERN WASH. R & J DAUBENMIRE 1968	BOISE & PAYETTE N.F. PFISTER & OTHERS 1973	CHALLIS, SALMON, & SAWTOOTH N.F. STEELE & OTHERS 1974	CENTRAL IDAHO REVIEW DRAFT STEELE & OTHERS 1975	CENTRAL IDAHO H.T.S.
				ABGR/CARU
	ABGR/ SPBE (IN PART)		ABGR/ SPBE	ABGR/ SPBE
	ABGR/ VAGL (IN PART)	ABGR/ VAGL (IN PART)	ABGR/ VAGL	ABGR/ VAGL
			ABGR/ XETE	ABGR/ XETE
	ABGR/SPBE (IN PART) ABGR/VAGL (IN PART)	ABGR/ VAGL (IN PART)	ABGR/ ACGL	ABGR/ ACGL PHMA ACGL
ABGR/PAMY (IN PART?)	ABGR/ VAGL (IN PART)	ABGR/ VAGL (IN PART)	ABGR/ LIBO VAGL	ABGR/ LIBO VAGL
				ABGR/ LIBO XETE
			ABGR/ COOC	ABGR/ COOC
ABGR/ PAMY	ABGR/ CLUN	ABGR/ CLUN	ABGR/ CLUN	ABGR/ CLUN
	ABLA/ CABI	ABLA/ CABI	ABLA/ CABI	ABLA/ CABI
ABLA/ PAMY (IN PART)	ABLA/ CLUN		ABLA/ CLUN	ABLA/ CLUN
ABLA/ MEFE	ABLA/ MEFE	ABLA/ MEFE	ABLA/ MEFE	ABLA/ MEFE
	ABLA/ VACA CACA	ABLA/ VACA CACA	ABLA/ VACA CACA	ABLA/ CACA VACA
	ABLA/ VACA VACA	ABLA/ VACA VACA	ABLA/ VACA VACA	ABLA/ VACA
	ABLA/ CACA LICA		ABLA/ CACA LICA	ABLA/ CACA LICA
	ABLA/ CACA CACA	ABLA/ CACA	ABLA/ CACA CACA	ABLA/ CACA CACA
	ABLA/ LICA	ABLA/ STAM	ABLA/ STAM	ABLA/ STAM LICA STAM
ABLA/ PAMY (IN PART)	ABLA/ VAGL (IN PART)		ABLA/ LIBO LIBO	ABLA/ LIBO LIBO
				ABLA/ LIBO XETE
		ABLA/ LIBO	ABLA/ LIBO VASC	ABLA/ LIBO VASC
	ABLA/ LEGL	ABLA/ LEGL	ABLA/ LEGL	ABLA/ CACA LEGL
	ABLA/ ACGL	ABLA/ ACGL	ABLA/ ACGL	ABLA/ ACGL
	ABLA/ XETE VAGL	ABLA/ XETE VAGL	ABLA/ XETE VAGL	ABLA/ XETE VAGL
ABLA/ XETE	ABLA/ XETE XETE	ABLA/ XETE XETE	ABLA/ XETE XETE	ABLA/ XETE VASC
				ABLA/ XETE LUHI
ABLA/ PAMY (IN PART)	ABLA/ VAGL (IN PART)	ABLA/ VAGL	ABLA/ VAGL	ABLA/ VAGL VASC VAGL
	ABLA/ SPBE	ABLA/ SPBE	ABLA/ SPBE	ABLA/ SPBE
	ABLA/ LUHI VASC		ABLA/ LUHI VASC	ABLA/ LUHI VASC
	ABLA/ LUHI LUHI		ABLA/ LUHI LUHI	ABLA/ LUHI LUHI
		ABLA/ VASC CARU	ABLA/ VASC CARU	ABLA/ VASC CARU
ABLA/ VASC	ABLA/ VASC	ABLA/ VASC VASC	ABLA/ VASC VASC	ABLA/ VASC VASC
				ABLA/ VASC PIAL
	ABLA/ CARU	ABLA/ CARU	ABLA/ CARU	ABLA/ CARU
		ABLA/ CAGE CAGE		
	ABLA/ CAGE CAGE	ABLA/ CAGE SYOR	ABLA/ CAGE CAGE	ABLA/ CAGE CAGE
	ABLA/ CAGE ARTR	ABLA/ CAGE ARTR	ABLA/ CAGE ARTR	ABLA/ CAGE ARTR
		ABLA/ JUCO	ABLA/ JUCO	ABLA/ JUCO
		ABLA/ RIMO	ABLA/ RIMO	ABLA/ RIMO
		ABLA/ ARCO	ABLA/ ARCO	ABLA/ ARCO
PIAL- ABLA	ABLA/ PIAL	PIAL- ABLA	PIAL- ABLA	PIAL- ABLA H. T. S.
			PIAL	PIAL H. T. S.
	PICO/ FEID	PICO/ FEID	PICO/ FEID	PICO/ FEID

USE OF THE CLASSIFICATION

Validation

This classification attempts to provide a natural stratification of forest lands in terms of vegetative development. It is designed to reflect the combined forces of the environment upon a given site and discounts the temporary alterations of disturbance. Although the actual environmental parameters of a vegetal unit are often unknown, the major importance of this classification lies in the knowledge of the relative positions of the vegetal units. As R. and J. Daubenmire (1968) have pointed out, "that system may be considered the closest to a natural one that allows the most predictions about a unit from a mere knowledge of its position in the system."

This classification reflects 6 years of sampling, preliminary drafts, and field testing by foresters. Suggested revisions were analyzed and often incorporated. These inputs have substantially improved the classification, but because this classification was developed through a series of approximations, it should always remain open to further refinement.

USE OF HABITAT TYPES

Layser (1974) and Pfister and others (1976) have outlined potential values of habitat types in resource management. Perhaps the most important use is a land stratification system — designating land areas with approximately equivalent environments or biotic potential — providing a tool for cataloging (1) research results, (2) administrative study results, (3) accumulated field observations, and (4) intuitive evaluations. The habitat type classification provides a foundation upon which to base predictions of response to activities related to vegetation management. One caution, however, is that habitat types are **not** a panacea for all decision making or interpretations. Habitat types **will** complement information on soils, outdoor recreation, socio-economic conditions, hydrology, and wildlife, and will aid development of more intensive land-management planning and practices. They also do not provide a substitute for maps or classifications of existing vegetation such as forest cover types.

Some of the current and potential uses of habitat types include:

1. Communication — provide a common framework for site recognition and interdisciplinary activities;

2. Timber management — stratification of seed source, species selection for planting, cutting and regeneration methods, assessing relative timber productivity;

3. Range and wildlife management — assessing relative forage production and wildlife habitat values;

4. Watershed — estimating relative plant available moisture levels and evapotranspiration rates; recognizing areas of heavy snowpack, and high water tables;

5. Recreation — assessing suitability for various types of recreational use, impacts of recreational use on the plant communities and sites, and esthetic recovery rates following stand disturbances;

6. Forest protection — categorization of fuel buildup, fuel management, and the natural role of fire (frequency and intensity of burns); assessment of susceptibility to various insects and diseases;

7. Natural area preservation — help insure that the environmental spectrum is adequately represented in research natural areas; and

8. Research — stratification tool for designing studies; reporting results in a format suitable for appropriate extrapolation.

Some management implications are discussed in the descriptions of the habitat types in this report. The appendix data can provide additional implications through interpretation by appropriate functional specialists. Field personnel can also document repeated observations to help expand our knowledge of vegetative reactions on specific habitat types.

Mapping

Habitat type maps have become an important management tool in the Northern Region of the USDA Forest Service (Deitschman 1973; Stage and Alley 1973; Daubenmire 1973). Maps provide a permanent record of habitat type distribution on the landscape and a basis for acreage estimates for land-use planning.

Maps may be made at various scales and degrees of accuracy, depending upon objectives. For research studies, project planning, etc., maps should be accurate and detailed; each phase of a habitat type should be delineated, especially for research studies. The map scale should range from 4 to 8 inches per mile. At a broader level of planning (multiple use planning unit, National Forests, etc.) map accuracy and detail may decrease and mapping efforts may be extensive. Habitat types are often the finest subdivisions shown, and map scale can range from one-half to 2 inches per mile.

Still broader levels of mapping may be required for regional needs (selection of powerline corridors, State or regional planning); these may employ scales of one-fourth to one-half inch per mile, and may depict only habitat type groups or series. These should be synthesized from large-scale habitat type maps whenever the latter are available.

Selecting a mapping approach and appropriate scale to produce an acceptable map must be based on the following: (1) anticipated use of the map, (2) accuracy level required, (3) availability of adequately trained personnel, and (4) amount of time and financial support available to achieve the specified accuracy level.

Table 4.--An example of grouping based on similar ecologic and geographic characteristics

Group	Components
1	*PIPO/STOC, PIPO/AGSP, PIPO/FEID*
2	*PIPO/PUTR, PIPO/SYOR*
3	*Pinus flexilis* series
4	*PSME/AGSP, PSME/FEID*
5	*PSME/SYOR, PSME/BERE SYOR* phase, *PSME/CAGE SYOR* phase
6	*PSME/ARCO, PSME/JUCO, PIEN/HYRE*
7	*PSME/CAGE CAGE* phase, *PSME/CARU CARU* phase, *PSME/SPBE CARU* phase
8	*PSME/SPBE SPBE* phase, *PSME/SYAL SYAL* phase
9	*PSME/BERE, PSME/OSCH*
10	*PSME/ACGL, PSME/PHMA PSME* phase
11	*ABGR/CARU, ABGR/SPBE*
12	*ABGR/VAGL, ABGR/ACGL, ABGR/LIBO, ABGR/CLUN*
13	*ABLA/CLUN, ABLA/LIBO, ABLA/ACGL*
14	*ABLA/VACA, PICO/FEID*
15	*ABLA/CACA, ABLA/STAM*
16	*ABLA/XETE, ABLA/VAGL*
17	*ABLA/VASC CARU* phase, *ABLA/CARU*
18	*ABLA/VASC VASC* phase, *ABLA/CAGE CAGE* phase
19	*ABLA/ARCO, ABLA/JUCO*
20	*ABLA/CAGE ARTR* phase, *PIAL-ABLA* h.t.'s, *PIAL* h.t.'s

At scales of 4 to 8 inches per mile, the habitat types or phases are useful as the mapping units, accepting inclusions (up to 15 percent) of other types too small to map separately. In complex topography and at smaller map scales, special mapping units must be developed, which may be called complexes or mosaics. Such mapping-unit complexes must be defined for each area being mapped, rather than on a preconceived grouping. The amount and relative positions of habitat types and phases within a complex must be specified because the management interpretations of a mapping unit are tied to the taxonomic units — series, habitat type, and phase.

Regardless of the mapping scale used, the field reconnaissance should identify stands to the phase level. The amount and location of field reconnaissance should also be specified on the map or in a report for users of the map. Finally, the map accuracy should be estimated and checked to maintain quality control in application of the habitat type classification.

Grouping

Because this classification system for potential vegetation is hierarchical, it can be used at various levels of differentiation for various purposes. Collecting and recording of field data (vegetation inventories) should be done with enough detail to allow for determination of habitat type and phase and should be recorded in a standard format such as a checklist (appendix F). Using this approach is only slightly more time-consuming than taking cruder field data, and it enhances the value of the data as well as the comprehension of the investigator and his professional credibility. Above all, it provides flexibility in the ultimate use of the data. In contrast, if data are collected at the habitat type group level, rearrangement or more detailed analysis is not possible.

In a given forested area, only a small percentage of all the forest habitat types and phases will occur. Moreover, some of these will be so minor in extent or so poorly developed that once their presence is documented they need not enter into most broad scale forest management considerations. This leaves a relatively small number of habitat types to be identified (and mapped) as such. After the distributional patterns of all the habitat types in a given area are identified, the types can be arranged in logical categories (table 4)

to facilitate resource planning and public presentations.

Where implications for management are similar, it may be desirable to consider an entire series, such as the *Pinus flexilis* series or *Abies grandis* series, as one group. Conversely, where management considerations contrast strongly even at the phase level, as in the phases of *PSME/CARU*, it may be desirable to split a habitat type in the grouping process.

Other bases for groupings may be useful for various specialists in resource management. Again, it is important to clarify that such groupings, if used at all in preference to habitat types alone, should be made **after** a thorough inventory has been completed at the habitat type level. Any group category used should include a record of the relative amounts of each habitat type (and phase) included therein to document the basis for general statement about the group.

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APPENDIX A. NUMBER OF SAMPLE STANDS BY HABITAT TYPE, PHASE, AND NATIONAL FOREST IN CENTRAL IDAHO

APPENDIX A · NUMBER OF SAMPLE STANDS BY HABITAT TYPE, PHASE, AND NATIONAL FOREST IN CENTRAL IDAHO

B = Boise National Forest
C = Challis National Forest
N = Nezperce National Forest
P = Payette National Forest
SL = Salmon National Forest
ST = Sawtooth National Forest
T = Targhee National Forest

Habitat type, phase	National Forest vicinity							
	B	C	N	P	SL	ST	T	Total
PINUS FLEXILIS SERIES								
PIFL/FEID	.	2	.	.	1	.	.	3
								3
PINUS PONDEROSA SERIES								
PIPO/STOC	3	.	.	.	.	.	.	3
PIPO/AGSP	11	.	1	5	1	.	.	18
PIPO/FEID	3	.	.	3	1	.	.	7
PIPO/PUTR, AGSP	6	.	.	2	3	.	.	11
PIPO/PUTR, FEID	1	.	.	2	.	.	.	3
PIPO/SYOR	2	.	.	1	.	.	.	3
PIPO/SYAL	5	.	.	5	1	.	.	11
								56
PSEUDOTSUGA MENZIESII SERIES								
PSME/AGSP	9	4	.	3	1	3	.	20
PSME/FEID, FEID	.	7	.	.	4	.	.	11
PSME/FEID, PIPO	1	.	.	2	3	.	.	6
PSME/SYOR	2	14	.	.	2	5	3	26
PSME/ARCO, ASMI	.	.	.	.	.	.	6	6
PSME/ARCO, ARCO	.	15	.	.	5	2	.	22
PSME/JUCO	.	7	.	.	2	2	2	13
PSME/CAGE, SYOR	4	1	.	.	1	5	.	11
PSME/CAGE, PIPO	8	.	.	5	.	.	.	13
PSME/CAGE, CAGE	2	3	.	.	.	9	.	14
PSME/BERE, SYOR	3	.	.	.	.	.	.	3
PSME/BERE, CAGE	2	.	.	.	.	3	.	5
PSME/BERE, BERE	10	.	.	.	.	3	.	13
PSME/CELE	.	2	.	.	3	.	1	6
PSME/CARU, FEID	1	.	.	.	1	.	.	2
PSME/CARU, PIPO	11	.	.	2	3	.	.	16
PSME/CARU, CARU	4	10	.	2	7	8	.	31
PSME/OSCH	5	.	.	2	.	.	.	7
PSME/SPBE, PIPO	19	.	.	6	.	.	.	25
PSME/SPBE, CARU	.	3	.	.	2	.	.	5
PSME/SPBE, SPBE	1	3	.	1	2	2	.	9
PSME/SYAL, PIPO	1	.	.	.	2	.	.	20
PSME/SYAL, SYAL	8	.	.	9	3	.	.	3
PSME/ACGL, SYOR	.	2	.	.	.	1	2	5
PSME/ACGL, ACGL	6	.	.	.	.	2	.	8
PSME/PHMA, PIPO	18	.	.	8	1	.	.	27
PSME/PHMA, PSME	7	2	.	1	2	1	.	13
								340
PICEA ENGELMANNII SERIES								
PIEN/HYRE	.	.	.	.	.	.	5	5
PIEN/CADI	.	2	.	.	3	1	1	7
								12

continued

APPENDIX A - NUMBER OF SAMPLE STANDS BY HABITAT TYPE, PHASE, AND NATIONAL FOREST IN CENTRAL IDAHO

Habitat type, phase	National Forest vicinity								
	B	C	N	P	SL	ST	T	Total	
***ABIES GRANDIS* SERIES**									
ABGR/CARU	2	.	.	5	.	.	.	7	
ABGR/SPBE	1	.	.	7	.	.	.	8	
ABGR/VAGL	8	.	1	3	.	.	.	12	
ABGR/ACGL, PHMA	5	.	1	6	.	.	.	12	
ABGR/ACGL, ACGL	5	.	1	8	.	.	.	14	
ABGR/LIBO, VAGL	3	.	.	1	.	.	.	4	
ABGR/LIBO, LIBO	1	.	2	1	.	.	.	4	
ABGR/VACA	2	.	.	6	.	.	.	8	
ABGR/CLUN	3	.	1	11	.	.	.	15	
									84
***ABIES LASIOCARPA* SERIES**									
ABLA/CABI	5	3	.	.	.	.	.	8	
ABLA/CACA, LEGL	.	3	3	2	2	1	.	11	
ABLA/CACA, VACA	3	2	1	.	.	2	.	8	
ABLA/CACA, LICA	2	.	1	11	.	.	.	14	
ABLA/CACA, CACA	2	2	.	1	1	1	.	7	
ABLA/STAM, LICA	1	.	1	9	.	.	.	11	
ABLA/STAM, STAM	2	2	.	1	1	1	.	7	
ABLA/CLUN	.	.	.	3	.	.	.	3	
ABLA/MEFE	5	.	1	2	.	.	.	8	
ABLA/ACGL	4	.	.	.	.	1	.	5	
ABLA/VACA	7	.	.	3	1	2	.	13	
ABLA/LIBO	2	.	.	.	2	.	.	4	
ABLA/XETE, VAGL	.	.	.	8	1	.	.	9	
ABLA/XETE, VASC	.	.	.	5	1	.	.	6	
ABLA/XETE, LUHI	.	.	2	3	.	.	.	5	
ABLA/VAGL	8	.	.	3	.	.	.	11	
ABLA/SPBE	4	.	.	.	.	3	.	7	
ABLA/LUHI, VASC	.	.	.	5	.	.	.	5	
ABLA/LUHI, LUHI	1	.	.	4	.	.	.	5	
ABLA/VASC, CARU	1	1	.	.	1	.	.	3	
ABLA/VASC, VASC	5	5	.	.	1	2	.	13	
ABLA/VASC, PIAL	1	1	.	.	.	1	.	3	
ABLA/CARU	6	4	.	3	1	1	.	15	
ABLA/CAGE, CAGE	8	6	.	1	1	14	.	30	
ABLA/CAGE, ARTR	2	1	.	.	.	.	.	3	
ABLA/JUCO	.	5	.	.	2	1	.	8	
ABLA/RIMO	.	1	.	.	.	2	2	5	
ABLA/ARCO	.	6	.	.	3	3	.	12	
PIAL-ABLA	6	4	1	3	.	1	.	15	
									254
***PINUS ALBICAULIS* SERIES**									
PIAL	1	1	.	.	2	1	.	5	
									5
***PINUS CONTORTA* SERIES**									
PICO/FEID	3	6	.	.	1	2	.	12	
									12
Unclassified stands	9	3	.	3	1	4	1	21	
									21
Total	271	126	17	177	77	88	23		787

APPENDIX B. OCCURRENCE AND ROLES OF TREE SPECIES BY HABITAT TYPES

Occurrence and Roles of Tree Species by Habitat Types

Occurrence of tree species through the series of habitat types, showing their status in forest succession as interpreted from central Idaho reconnaissance plot data.

C = major climax species   S = major seral species   a = accidental
c = minor climax species   x = minor seral species   ( ) = only in certain areas of h.t.

Habitat Type, Phase	JUSC	POTR	PIFL	PIPO	PSME	PICO	PIEN	LAOC	ABGR	ABLA	PI
PIFL/FEID	(c)	.	C	.	C	.	.	.	.	.	.
PIPO/STOC	.	.	.	C	.	.	.	.	.	.	.
PIPO/AGSP	.	.	.	C	a	.	.	.	.	.	.
PIPO/FEID	.	a	.	C	a	.	.	.	.	.	.
PIPO/PUTR, AGSP	.	a	.	C	a	.	.	.	.	.	.
PIPO/PUTR, FEID	.	.	.	C	a	.	.	.	.	.	.
PIPO/SYOR	.	.	.	C	a	.	.	.	.	.	.
PIPO/SYAL	.	(s)	.	C	a	.	.	.	.	.	.
PSME/AGSP	.	a	.	(C)	C	.	.	.	.	.	.
PSME/FEID, FEID	.	.	.	.	C	a	.	.	.	.	.
PSME/FEID, PIPO	.	.	.	C	C	a	.	.	.	.	.
PSME/SYOR	.	a	(c)	(c)	C	a	.	.	.	.	.
PSME/ARCO, ASMI	a	.	s	.	C	.	a	.	.	.	.
PSME/ARCO, ARCO	.	a	(s)	.	C	(s)	a	.	.	a	a
PSME/JUCO	.	.	(s)	.	C	(s)	.	.	.	a	a
PSME/CAGE, SYOR	.	a	a	.	C	(s)	.	.	.	a	a
PSME/CAGE, PIPO	.	.	.	S	C	a	.	.	.	.	.
PSME/CAGE, CAGE	.	a	a	.	C	(s)	.	.	.	a	a
PSME/BERE, SYOR	.	.	.	(c)	C	.	.	.	.	.	.
PSME/BERE, CAGE	.	.	.	S	C	.	.	.	.	.	.
PSME/BERE, BERE	.	.	.	(S)	C	(c)	.	.	.	.	.
PSME/CELE	.	.	(c)	(C)	C	a	.	.	.	.	.
PSME/CARU, FEID	.	.	.	.	C	.	.	.	.	.	.
PSME/CARU, PIPO	.	.	.	S	C	(S)	.	.	.	.	.
PSME/CARU, CARU	.	s	.	.	C	(S)	a	.	.	a	a
PSME/OSCH	.	.	.	(S)	C	.	.	.	.	a	.
PSME/SPBE, PIPO	.	a	.	S	C	a	a	.	.	a	.
PSME/SPBE, CARU	.	.	.	.	C	(S)	.	.	.	.	.
PSME/SPBE, SPBE	.	.	a	.	C	(s)	.	.	.	a	.
PSME/SYAL, PIPO	.	(s)	.	S	C	(s)	.	.	.	.	.
PSME/SYAL, SYAL	.	a	.	.	C	a	.	.	.	a	.
PSME/ACGL, SYOR	s	.	s	.	C	.	.	.	.	.	.
PSME/ACGL, ACGL	.	(S)	.	(S)	C	.	.	.	.	a	.
PSME/PHMA, PIPO	.	.	.	S	C	.	.	.	.	a	.
PSME/PHMA, PSME	.	.	.	.	C	.	.	.	.	.	.
PIEN/HYRE	.	.	s	.	C	.	C	.	.	.	.
PIEN/CADI	.	a	.	.	a	s	C	.	.	c	.

(con.)

APPENDIX B. (con.)

Habitat Type, Phase	JUSC	POTR	PIFL	PIPO	PSME	PICO	PIEN	LAOC	ABGR	ABLA	PIAL
ABGR/CARU	.	.	.	S	S	(S)	a	.	C	a	a
ABGR/SPBE	.	(s)	.	S	S	.	a	a	C	.	.
ABGR/VAGL	.	a	.	s	S	S	S	(s)	C	(c)	.
ABGR/ACGL, PHMA	.	.	.	S	S	.	a	a	C	(c)	.
ABGR/ACGL, ACGL	.	.	.	S	S	.	a	a	C	(c)	.
ABGR/LIBO, VAGL	.	.	.	s	S	S	S	(s)	C	(c)	.
ABGR/LIBO, LIBO	.	.	.	S	S	s	a	a	C	.	.
ABGR/VACA	.	.	.	(s)	(S)	S	s	s	C	c	.
ABGR/CLUN	.	.	.	s	S	(s)	S	S	C	(c)	.
ABLA/CABI	.	a	.	.	.	s	S	.	.	C	.
ABLA/CACA, LEGL	.	.	.	.	s	S	S	.	a	C	a
ABLA/CACA, VACA	.	(s)	.	.	a	S	s	.	a	C	.
ABLA/CACA, LICA	.	.	.	.	a	s	S	.	.	C	.
ABLA/CACA CACA	.	a	.	.	a	S	S	.	.	C	.
ABLA/STAM, LICA	.	.	.	.	a	s	S	.	a	C	.
ABLA/STAM, STAM	.	.	.	.	a	s	S	.	.	C	.
ABLA/CLUN CLUN	.	.	.	a	S	s	S	(S)	(c)	C	.
ABLA/MEFE, MEFE	.	.	.	.	s	(S)	S	(S)	(c)	C	.
ABLA/ACGL	.	a	.	.	S	.	.	.	.	C	.
ABLA/VACA	.	a	.	.	s	S	s	.	a	C	s
ABLA/LIBO, LIBO	.	.	.	.	S	S	S	.	a	C	a
ABLA/XETE, VAGL	.	.	.	.	(S)	S	S	.	.	C	.
ABLA/XETE, VASC	.	.	.	.	(S)	S	s	.	.	C	(s)
ABLA/XETE, LUHI	.	.	.	.	.	(s)	(s)	.	.	C	s
ABLA/VAGL, VAGL	.	.	.	a	S	s	S	.	a	C	a
ABLA/SPBE	.	.	.	a	S	(S)	a	.	.	C	a
ABLA/LUHI, VASC	.	.	.	.	.	S	s	.	.	C	s
ABLA/LUHI, LUHI	.	.	.	.	.	s	s	.	.	C	s
ABLA/VASC, CARU	.	.	.	.	s	S	s	.	.	C	.
ABLA/VASC, VASC	.	.	.	.	a	S	s	.	.	C	s
ABLA/VASC, PIAL	.	.	.	.	.	(S)	a	.	.	C	C
ABLA/CARU	.	.	.	.	S	S	.	.	a	C	s
ABLA/CAGE, CAGE	.	a	.	.	(S)	(S)	(s)	.	.	C	s
ABLA/CAGE, ARTR	.	.	.	.	(s)	a	.	.	.	C	c
ABLA/JUCO	.	.	.	.	(S)	(S)	s	.	.	C	s
ABLA/RIMO	.	.	.	.	a	.	(s)	.	.	C	S
ABLA/ARCO	.	.	.	.	S	(S)	S	.	.	C	s
PIAL/ABLA	.	.	.	.	.	(s)	a	.	.	C	C
PICO/FEID	.	.	.	.	.	C	.	.	.	.	(c)

APPENDIX C-1

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in central Idaho habitat types and phases

CODE NUMBER	SPECIES	PIFL SERIES: FEID h.t.	PINUS PONDEROSA SERIES: TOC h.t.	AGSP h.t.	FEID h.t.	PUTR h.t.: FEID phase	PUTR h.t.: AGSP Phase	SYOR h.t.	SYAL h.t.	PSEUDOTSUGA MENZIESII SERIES: AGSP h.t.	FEID h.t.: PIPO Phase	FEID h.t.: FEID phase	CELE h.t.	SYOR h.t.
		n [illegible]	[illegible]	n [illegible]	n [illegible]	[illegible]	n = 11	n = 3	n = 11	n = 20	n [illegible]	n = 11	n [illegible]	n [illegible]
	TREES													
001	Abies grandis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
002	Abies lasiocarpa	- (0)	- (0)	- (0)	(0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
006	Larix occidentalis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
007	Picea engelmannii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
009	Pinus albicaulis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (3)	- (0)	+ (3)
[illegible]	Pinus contorta	- (0)	- (0)	1 (1)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	3 (2)	1 (3)	3 (2)	1 (1)
011	Pinus flexilis	10 (23)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (0)	2 (1)	- (0)	2 (0)	2 (5)
[illegible]	Pinus ponderosa	[illegible]	10 (30)	10 (24)	10 (35)	10 (30)	10 (30)	10 (23)	10 (48)	5 (15)	10 (22)	- (0)	2 (37)	1 (20)
014	Populus tremuloides	- (0)	[illegible] (0)	- ([illegible])	1 (1)	- (0)	1 (1)	- (0)	3 (5)	1 (3)	- (0)	- (0)	- (0)	1 (8)
016	Pseudotsuga menziesii	10 ([illegible])	- ([illegible])	- ([illegible])	[illegible] (0)	- ([illegible])	[illegible] (2)	7 (0)	1 (0)	10 (27)	10 (17)	10 (34)	10 (17)	10 (47)
	SHRUBS and SUBSHRUBS													
[illegible]	Acer glabrum	- ([illegible])	- (0)	- (0)	1 (1)	- (0)	1 (0)	- (0)	- (0)	2 (0)	- (0)	- (0)	2 (3)	1 (1)
104	Alnus sinuata	- (0)	- (0)	- (0)	- ([illegible])	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
[illegible]	Amelanchier alnifolia	- (0)	7 (1)	[illegible] (1)	6 (1)	7 (0)	[illegible] (5)	10 (1)	8 (6)	5 (1)	7 (1)	- (0)	2 (1)	2 (2)
[illegible]	Arctostaphylos uva-ursi	[illegible]	- (0)	- (0)	- (0)	- (0)	[illegible]	- (0)	- (0)	1 (1)	- (0)	1 (0)	3 (1)	+ (1)
[illegible]	Artemisia tridentata	10 (1)	3 (1)	2 (1)	7 (14)	[illegible] (1)	2 (3)	3 (15)	1 (1)	6 (10)	5 (6)	9 (10)	5 (11)	6 (9)
[illegible]	Berberis repens	[illegible]	[illegible]	[illegible] (4)	- (0)	- (0)	1 (1)	[illegible]	[illegible] (1)	2 (1)	2 (3)	- (0)	3 (2)	1 (0)
107	Ceanothus velutinus	- (0)	[illegible]	1 (1)	- (0)	- (0)	1 (1)	- (0)	4 (1)	4 (3)	2 (0)	- (0)	- (0)	+ (3)
[illegible]	Cercocarpus ledifolius	3 (1)	- (0)	1 (3)	1 ([illegible])	- (0)	- ([illegible])	- (0)	- (0)	1 (3)	2 (1)	- (0)	10 (42)	1 (2)
[illegible]	Clematis columbiana	[illegible]	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
205	Gaultheria humifusa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
111	Holodiscus discolor	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
112	Juniperus communis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (1)	5 (0)	3 (2)
113	Ledum glandulosum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
206	Linnaea borealis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
154	Lonicera caerulea	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
115	Lonicera utahensis	- (0)	- (0)	(0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
116	Menziesia ferruginea	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
118	Pachistima myrsinites	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
122	Physocarpus malvaceus	- (0)	- (0)	1 (0)	1 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	+ (1)
124	Prunus virginiana	- (0)	- (0)	3 ([illegible])	1 (3)	7 (2)	4 (2)	7 (8)	7 (2)	5 (1)	2 (1)	- (0)	2 (1)	2 (16)
125	Purshia tridentata	- (0)	10 (1)	6 (1)	3 (2)	10 (23)	10 (25)	10 (6)	3 (2)	5 (2)	5 (6)	- (0)	3 (9)	2 (1)
128	Ribes cereum	- (0)	- (0)	2 (2)	7 (1)	3 (0)	1 (1)	7 (1)	4 (5)	5 (1)	5 (1)	5 (1)	3 (9)	7 (8)
130	Ribes lacustre	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
159	Ribes montigenum	7 ([illegible])	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (3)	- (0)	- (0)
131	Ribes viscosissimum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)
133	Rosa gymnocarpa	- (0)	- (0)	- (0)	- (0)	- (0)	1 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
161	Rosa nutkana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	5 (3)	- (0)	- (0)	- (0)	- (0)	- (0)
134	Rosa woodsii	- (0)	- (0)	1 (1)	3 (2)	- (0)	2 (2)	3 (1)	4 (2)	2 (4)	5 (1)	- (0)	2 (3)	1 (2)
136	Rubus parviflorus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
137	Salix scouleriana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (3)	2 (2)	- (0)	- (0)	- (0)	- (0)	- (0)
139	Sheperdia canadensis	3 (1)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (37)
140	Sorbus scopulina	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
142	Spiraea betulifolia	- (0)	- (0)	2 (4)	3 (2)	- (0)	3 (1)	- (0)	2 (39)	1 (1)	2 (1)	- (0)	- (0)	+ (3)
162	Spiraea pyramidata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
143	Symphoricarpos albus	- (0)	- (0)	1 (3)	3 (1)	3 (3)	- (0)	- (0)	10 (41)	1 (0)	2 (0)	- (0)	- (0)	- (0)
163	Symphoricarpos oreophilus	10 (1)	3 (1)	1 (1)	- (0)	3 (1)	1 (0)	10 (11)	3 (1)	5 (2)	2 (1)	5 (1)	7 (5)	9 (21)
144	Taxus brevifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
145	Vaccinium caespitosum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
146	Vaccinium globulare	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
148	Vaccinium scoparium	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
	FERNS and FERN ALLIES													
253	Cystopteris fragilis	- (0)	- (0)	2 (1)	3 (2)	- (0)	1 (1)	- (0)	1 (1)	2 (0)	5 (2)	2 (1)	- (0)	- (0)
254	Equisetum arvense	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
259	Pteridium aquilinum	- (0)	- (0)	1 (15)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
	GRAMINOIDS													
301	Agropyron spicatum	7 (31)	3 (1)	10 (25)	9 (14)	7 (26)	9 (17)	10 (6)	5 (4)	9 (27)	8 (24)	7 (14)	10 (24)	7 (11)
304	Bromus vulgaris	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
305	Calamagrostis canadensis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
307	Calamagrostis rubescens	- (0)	- (0)	1 (1)	- (0)	- (0)	2 (9)	- (0)	5 (41)	- (0)	2 (1)	2 (1)	2 (1)	1 (3)
308	Carex concinnoides	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	2 (1)	+ (1)
339	Carex disperma	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
309	Carex geyeri	- (0)	7 (1)	1 (1)	3 (2)	3 (3)	1 (1)	7 (0)	5 (15)	2 (2)	3 (1)	2 (1)	- (0)	2 (2)
311	Carex rossii	7 (1)	7 (2)	1 (1)	4 (1)	3 (1)	5 (1)	7 (0)	4 (1)	2 (1)	5 (1)	2 (1)	8 (1)	3 (1)
316	Elymus glaucus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	5 (1)	- (0)	- (0)	- (0)	- (0)	+ (1)
317	Festuca idahoensis	10 (23)	3 (0)	3 (2)	10 (33)	10 (18)	3 (2)	3 (1)	1 (1)	3 (1)	10 (41)	10 (23)	2 (37)	3 (21)
348	Hesperochloa kingii	7 (15)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (2)	- (0)	3 (2)	2 (15)	2 (4)
322	Juncus parryi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
323	Koeleria cristata	3 (1)	- (0)	1 (1)	3 (1)	3 (1)	3 (1)	- (0)	- (0)	- (0)	3 (1)	2 (3)	2 (1)	1 (1)
325	Luzula hitchcockii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
349	Melica bulbosa	- (0)	- (0)	3 (13)	1 (1)	- (0)	1 (1)	3 (1)	1 (1)	3 (7)	- (0)	- (0)	- (0)	2 (1)
331	Poa nervosa	3 (1)	- (0)	1 (15)	- (0)	- (0)	2 (1)	3 (1)	- (0)	3 (6)	- (0)	- (0)	2 (1)	4 (4)
360	Stipa occidentalis	- (0)	10 (23)	1 (0)	3 (3)	- (0)	1 (1)	3 (1)	- (0)	- (0)	- (0)	- (0)	3 (1)	1 (2)

* Code to constancy values:

+ = 0- 5%
1 = 5-15%
2 = 15-25%
3 = 25-35%
4 = 35-45%
5 = 45-55%
6 = 55-65%
7 = 65-75%
8 = 75-85%
9 = 85-95%
10 = 95-100%

ADP NUMBER	SPECIES	PIFL	PINUS PONDEROSA SERIES (con)							PSEUDOTSUGA MENZIESII SERIES (con)				
		FEID h.t.	STOC h.t.	AGSP h.t.	FEID h.t.	PUTR h.t		SYOR h.t.	SYAL h.t.	AGSP h.t.	FEID h.t.		CELE h.t.	SYOR h.t.
						FEID Phase	AGSP Phase				PIPO Phase	FEID Phase		
	FORBS	n= 3	n= 3	n=18	n= 7	n= 3	n=11	n=3	n=11	n=20	n= 6	n=11	n= 6	n=26
401	Achillaea millefollium	3 (1)	10 (1)	5 (1)	10 (1)	10 (2)	6 (3)	7 (1)	9 (1)	3 (1)	8 (1)	5 (1)	7 (1)	3 (1)
402	Actaea rubra	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
565	Aconitum columbianum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
403	Adenocaulon bicolor	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
738	Antennaria corymbosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
414	Antennaria microphylla	10 (1)	- (0)	1 (1)	1 (1)	3 (1)	3 (1)	- (0)	1 (1)	2 (1)	2 (1)	10 (3)	8 (1)	5 (5)
413	Antennaria racemosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (1)	- (0)	1 (1)	- (0)	+ (1)
577	Arenaria aculeata	- (0)	- (0)	1 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	2 (1)	+ (1)
420	Arenaria macrophylla	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	2 (1)	1 (3)	2 (0)	- (0)	- (0)	- (0)
421	Arnica cordifolia	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	3 (18)	- (0)	2 (3)	2 (3)	2 (1)	2 (1)
422	Arnica latifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
426	Aster conspicuus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
582	Aster engelmannii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)
430	Astragalus miser	3 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)
431	Balsamorhiza sagittata	- (0)	3 (3)	7 (12)	6 (15)	7 (15)	5 (9)	10 (14)	4 (8)	5 (5)	- (0)	2 (9)	7 (2)	1 (15)
696	Caltha biflora	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
741	Castilleja covilleana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
438	Castilleja miniata	3 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (1)	- (0)
595	Chaenactis douglasii	- (0)	- (0)	3 (0)	1 (1)	- (0)	2 (1)	- (0)	- (0)	4 (0)	- (0)	- (0)	- (0)	- (0)
442	Chimaphila umbellata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
447	Clintonia uniflora	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
449	Coptis occidentalis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
602	Crepis accuminata	3 (1)	- (0)	3 (1)	4 (1)	3 (3)	4 (1)	3 (1)	3 (1)	4 (1)	- (0)	- (0)	3 (2)	3 (1)
458	Dodecatheon jeffreyi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
455	Disporum trachycarpum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
459	Epilobium angustifolium	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	3 (1)	- (0)	- (0)	1 (1)	- (0)	+ (1)
465	Fragaria vesca	- (0)	- (0)	- (0)	1 (1)	- (0)	4 (1)	- (0)	3 (2)	1 (2)	3 (1)	1 (1)	- (0)	1 (1)
466	Fragaria virginiana	- (0)	- (0)	- (0)	1 (3)	3 (1)	2 (1)	- (0)	2 (9)	1 (0)	3 (2)	2 (1)	2 (1)	+ (1)
471	Galium triflorum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (1)	- (0)	- (0)	- (0)	- (0)
620	Geranium richardsonii	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	3 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)
473	Geranium viscosissimum	- (0)	3 (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	5 (1)	1 (1)	- (0)	- (0)	- (0)	1 (2)
474	Geum triflorum	7 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	3 (1)	5 (1)	3 (1)	2 (3)
476	Goodyera oblongifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
484	Hieracium albiflorum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	1 (1)
486	Hieracium gracile	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
636	Lathyrus nevadensis	- (0)	- (0)	1 (1)	- (0)	- (0)	1 (1)	3 (1)	3 (1)	- (0)	2 (15)	- (0)	- (0)	- (0)
489	Ligusticum canbyi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
490	Ligusticum tenuifolium	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
497	Lomatium dissectum	- (0)	- (0)	4 (10)	- (0)	- (0)	3 (1)	- (0)	- (0)	6 (8)	3 (1)	- (0)	- (0)	2 (0)
641	Lupinus argenteus	- (0)	- (0)	- (0)	1 (1)	3 (1)	- (0)	- (0)	1 (1)	- (0)	- (0)	1 (3)	- (0)	1 (1)
642	Lupinus polyphyllus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
649	Mitella pentandra	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
502	Mitella stauropetala	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
505	Osmorhiza chilensis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (0)	4 (5)	- (0)	- (0)	- (0)	- (0)	+ (1)
653	Osmorhiza depauperata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	+ (1)
507	Pedicularis bracteosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
509	Pedicularis racemosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
514	Penstemon wilcoxii	- (0)	- (0)	- (0)	1 (1)	- (0)	2 (1)	- (0)	1 (1)	2 (1)	2 (1)	- (0)	- (0)	- (0)
663	Phacelia hastata	- (0)	- (0)	3 (1)	- (0)	- (0)	5 (1)	- (0)	- (0)	4 (1)	- (0)	1 (1)	2 (1)	2 (1)
669	Potentilla diversifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
521	Potentilla flabellifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
670	Potentilla gracilis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (1)	4 (1)	- (0)	3 (1)	- (0)	2 (1)	- (0)
526	Pyrola asarifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
529	Pyrola secunda	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
676	Saxifraga arguta	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
538	Senecio pseudaureus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
681	Senecio streptanthifolius	3 (1)	- (0)	- (0)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	3 (1)
539	Senecio triangularis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
542	Smilacina racemosa	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	3 (0)	3 (1)	2 (1)	3 (1)	- (0)	- (0)	2 (1)
543	Smilacina stellata	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	1 (0)
684	Solidago multiradiata	- (0)	- (0)	- (0)	- (0)	- (0)	2 (2)	- (0)	- (0)	- (0)	2 (1)	1 (1)	5 (1)	- (0)
546	Streptopus amplexifolius	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
547	Thalictrum occidentalis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (2)	- (0)	- (0)	- (0)	- (0)	+ (3)
563	Trautvetteria caroliniensis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
560	Trillium ovatum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
551	Valeriana sitchensis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
552	Veratrum viride	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	+ (1)
554	Viola adunca	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
693	Viola nuttallii	- (0)	- (0)	1 (1)	- (0)	- (0)	1 (1)	- (0)	2 (1)	- (0)	- (0)	2 (1)	- (0)	+ (3)
557	Viola orbiculata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
694	Viola purpurea	- (0)	3 (0)	3 (1)	- (0)	3 (1)	2 (1)	3 (0)	- (0)	4 (1)	- (0)	- (0)	3 (0)	1 (1)
558	Xerophyllum tenax	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in central Idaho habitat types and phrases.

ADP NUMBER	SPECIES	PSEUDOTSUGA MENZIESII SERIES (con)											
		ARCO h.t.		JUCO h.t.	CAGE h.t.			BERE h.t.			CARU h.t.		
		ASMI Phase	ARCO Phase		SYOR Phase	CAGE Phase	PIPO Phase	SYOR Phase	BERE Phase	CAGE Phase	PIPO Phase	CARU Phase	FEID Phase
		n= 6	n=22	n=13	n=11	n=14	n=13	n= 3	n=13	n= 5	n=16	n=31	n= 2
	TREES												
001	Abies grandis	- (0)	- (0)	- (0)	- (0)	- (0)	1 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
002	Abies lasiocarpa	- (0)	1 (14)	- (0)	1 (15)	2 (1)	- (0)	3 (0)	- (0)	2 (0)	- (0)	2 (1)	- (0)
006	Larix occidentalis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
007	Picea engelmannii	2 (1)	1 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)	- (0)
009	Pinus albicaulis	- (0)	1 (1)	1 (3)	1 (1)	1 (8)	1 (0)	- (0)	- (0)	- (0)	- (0)	+ (3)	- (0)
010	Pinus contorta	- (0)	1 (22)	2 (9)	2 (0)	3 (16)	1 (1)	- (0)	1 (37)	- (0)	4 (22)	5 (20)	- (0)
011	Pinus flexilis	7 (10)	1 (6)	5 (7)	1 (1)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
013	Pinus ponderosa	- (0)	- (0)	- (0)	- (0)	- (0)	10 (45)	- (0)	4 (8)	6 (22)	10 (30)	- (0)	- (0)
014	Populus tremuloides	- (0)	+ (1)	- (0)	1 (3)	1 (1)	- (0)	- (0)	2 (13)	- (0)	1 (19)	4 (9)	- (0)
016	Pseudotsuga menziesii	10 (50)	10 (55)	10 (60)	10 (33)	10 (48)	8 (24)	10 (40)	10 (58)	10 (52)	8 (31)	10 (47)	10 (50)
	SHRUBS and SUBSHRUBS												
102	Acer glabrum	2 (0)	2 (4)	2 (1)	- (0)	3 (4)	- (0)	- (0)	3 (1)	6 (0)	1 (1)	1 (2)	- (0)
104	Alnus sinuata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
105	Amelanchier alnifolia	- (0)	1 (5)	- (0)	1 (1)	1 (1)	10 (4)	7 (2)	9 (6)	6 (7)	4 (5)	1 (1)	- (0)
201	Arctstaphylos uva-ursi	- (0)	- (0)	1 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (32)	+ (37)	- (0)
150	Artemisia tridentata	5 (1)	1 (1)	2 (5)	6 (26)	3 (1)	2 (8)	3 (1)	- (0)	2 (1)	1 (2)	2 (4)	5 (15)
203	Berberis repens	- (0)	1 (1)	- (0)	3 (4)	4 (1)	5 (1)	10 (31)	10 (19)	10 (24)	6 (1)	4 (3)	10 (1)
107	Ceanothus velutinus	- (0)	- (0)	- (0)	1 (1)	- (0)	3 (2)	3 (3)	1 (1)	- (0)	1 (20)	2 (25)	- (0)
173	Cercocarpus ledifolius	2 (1)	1 (2)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (0)	- (0)	- (0)
204	Clematis columbiana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	1 (0)	- (0)	- (0)
205	Gaultheria humifusa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
111	Holodiscus discolor	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
112	Juniperus communis	3 (0)	5 (1)	10 (24)	1 (1)	1 (0)	- (0)	- (0)	- (0)	- (0)	1 (2)	1 (0)	- (0)
113	Ledum glandulosum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
206	Linnaea borealis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
154	Lonicera caerulea	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
115	Lonicera utahensis	- (0)	- (0)	- (0)	1 (1)	1 (1)	2 (1)	- (0)	- (0)	- (0)	1 (1)	+ (1)	- (0)
116	Menziesia ferruginea	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
118	Pachistima myrsinites	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
122	Physocarpus malvaceus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	1 (0)	- (0)
124	Prunus virginiana	2 (3)	1 (1)	- (0)	2 (14)	1 (2)	5 (8)	10 (33)	4 (29)	6 (18)	6 (9)	- (0)	- (0)
125	Purshia tridentata	- (0)	- (0)	2 (2)	1 (15)	1 (1)	5 (1)	- (0)	1 (1)	- (0)	4 (12)	1 (1)	- (0)
128	Ribes cereum	7 (1)	3 (3)	5 (7)	5 (1)	5 (5)	2 (7)	7 (1)	1 (1)	2 (1)	4 (1)	3 (1)	5 (1)
130	Ribes lacustre	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (3)	- (0)
159	Ribes montigenum	2 (1)	1 (1)	1 (1)	- (0)	1 (8)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
131	Ribes viscosissimum	- (0)	1 (0)	2 (1)	- (0)	1 (1)	- (0)	3 (1)	- (0)	- (0)	1 (1)	1 (2)	- (0)
133	Rosa gymnocarpa	- (0)	- (0)	- (0)	- (0)	- (0)	2 (2)	- (0)	- (0)	- (0)	1 (3)	- (0)	- (0)
161	Rosa nutkana	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	2 (5)	- (0)	- (0)
134	Rosa woodsii	- (0)	1 (0)	- (0)	- (0)	- (0)	1 (1)	3 (15)	4 (1)	2 (1)	3 (1)	1 (2)	- (0)
136	Rubus parviflorus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
137	Salix scouleriana	- (0)	- (0)	- (0)	- (0)	3 (1)	2 (0)	3 (3)	1 (0)	- (0)	3 (2)	2 (3)	- (0)
139	Sheperdia canadensis	5 (1)	3 (3)	5 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (5)	1 (0)	- (0)
140	Sorbus scopulina	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	3 (3)	3 (2)	2 (1)	- (0)	- (0)	- (0)
142	Spiraea betulifolia	- (0)	- (0)	2 (1)	- (0)	- (0)	3 (2)	- (0)	- (0)	- (0)	4 (3)	3 (1)	5 (3)
162	Spiraea pyramidata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
143	Symphoricarpos albus	- (0)	- (0)	- (0)	- (0)	- (0)	3 (2)	- (0)	- (0)	2 (3)	3 (2)	- (0)	- (0)
163	Symphoricarpos oreophilus	7 (1)	9 (10)	8 (9)	10 (21)	9 (2)	5 (10)	10 (54)	9 (7)	8 (7)	4 (14)	9 (4)	5 (1)
144	Taxus brevifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
145	Vaccinium caespitosum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (0)	- (0)	- (0)
146	Vaccinium globulare	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)
148	Vaccinium scoparium	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)
	FERNS and FERN ALLIES												
253	Cystopteris fragilis	- (0)	- (0)	- (0)	1 (1)	- (0)	1 (1)	- (0)	1 (2)	- (0)	1 (1)	- (0)	- (0)
254	Equisetum arvense	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
259	Pteridium aquilinum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
	GRAMINOIDS												
301	Agropyron spicatum	5 (1)	2 (0)	- (0)	9 (6)	4 (2)	4 (4)	- (0)	- (0)	2 (3)	5 (1)	1 (1)	- (0)
304	Bromus vulgaris	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (3)	1 (37)	2 (1)	- (0)	- (0)	- (0)
305	Calamagrostis canadensis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
307	Calamagrostis rubescens	- (0)	1 (3)	1 (0)	1 (1)	5 (1)	3 (2)	- (0)	1 (3)	4 (3)	10 (34)	10 (60)	10 (26)
308	Carex concinnoides	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (0)	- (0)
339	Carex disperma	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
309	Carex geyeri	- (0)	2 (2)	2 (1)	10 (26)	10 (24)	10 (35)	3 (3)	7 (16)	10 (43)	8 (15)	8 (11)	10 (8)
311	Carex rossii	2 (1)	4 (0)	4 (1)	1 (1)	6 (1)	2 (1)	- (0)	3 (1)	- (0)	5 (1)	2 (1)	5 (1)
316	Elymus glaucus	- (0)	- (0)	1 (37)	- (0)	- (0)	1 (1)	- (0)	1 (1)	- (0)	1 (0)	- (0)	- (0)
317	Festuca idahoensis	5 (13)	5 (4)	3 (2)	3 (6)	1 (9)	4 (1)	- (0)	- (0)	2 (1)	3 (8)	3 (1)	10 (15)
348	Hesperochloa kingii	7 (1)	3 (1)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
322	Juncus parryi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
323	Koeleria cristata	- (0)	- (0)	- (0)	1 (2)	1 (1)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
325	Luzula hitchcockii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
349	Melica bulbosa	- (0)	- (0)	- (0)	3 (1)	1 (2)	1 (1)	3 (1)	1 (3)	- (0)	- (0)	- (0)	- (0)
331	Poa nervosa	8 (1)	6 (2)	2 (1)	9 (3)	6 (2)	6 (1)	- (0)	2 (1)	2 (1)	5 (1)	6 (3)	10 (1)
360	Stipa occidentalis	- (0)	- (0)	- (0)	2 (2)	1 (1)	2 (1)	- (0)	1 (1)	- (0)	3 (1)	1 (1)	- (0)

*Code to constancy values: + = 0-5 %, 1 = 5-15%, 2 = 15-25%, 3 = 25-35%, 4 = 35-45%, 5 = 45-55%, 6 = 55-65%, 7 = 65-75%, 8 = 75-85%, 9 = 85-95%, 10 = 95-100%

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in central Idaho habitat types and phrases.

		PSEUDOTSUGA MENZIESII SERIES (con)											
ADP NUMBER	SPECIES	ARCO h.t.		JUCO h.t.	CAGE h.t.			BERE h.t.			CARU h.t.		
		ASMI Phase	ARCO Phase		SYOR Phase	CAGE Phase	PIPO Phase	SYOR Phase	BERE Phase	CAGE Phase	PIPO Phase	CARU Phase	FEID Phase
		n= 6	n=22	n=13	n=11	n=14	n=13	n= 3	n=13	n= 5	n=16	n=31	n= 2
	FORBS												
401	Achillaea millefollium	3 (1)	1 (1)	3 (1)	5 (1)	5 (0)	6 (1)	- (0)	2 (1)	4 (1)	7 (1)	5 (2)	- (0)
402	Actaea rubra	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
565	Aconitum columbianum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
403	Adenocaulon bicolor	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
738	Antennaria corymbosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
414	Antennaria microphylla	8 (2)	3 (1)	3 (2)	2 (1)	4 (1)	2 (1)	- (0)	- (0)	- (0)	5 (1)	4 (1)	5 (1)
413	Antennaria racemosa	- (0)	2 (8)	2 (19)	- (0)	- (0)	1 (3)	- (0)	- (0)	- (0)	1 (0)	2 (3)	- (0)
577	Arenaria aculeata	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
420	Arenaria macrophylla	- (0)	- (0)	- (0)	1 (1)	1 (3)	2 (1)	3 (1)	3 (1)	2 (1)	4 (1)	1 (1)	- (0)
421	Arnica cordifolia	3 (2)	10 (18)	7 (14)	4 (4)	5 (17)	5 (5)	- (0)	6 (6)	6 (2)	6 (8)	7 (16)	5 (3)
422	Arnica latifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
426	Aster conspicuus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (3)	3 (1)	4 (1)	1 (37)	1 (2)	- (0)
582	Aster engelmannii	- (0)	+ (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
430	Astragalus miser	8 (31)	3 (8)	1 (15)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (15)	- (0)	- (0)
431	Balsamorhiza sagittata	2 (1)	1 (1)	- (0)	4 (7)	1 (19)	5 (4)	3 (1)	2 (1)	2 (1)	3 (0)	2 (2)	- (0)
696	Caltha biflora	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
741	Castilleja covilleana	- (0)	- (0)	- (0)	- (0)	- (0)	1 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
438	Castilleja miniata	- (0)	1 (1)	2 (1)	1 (1)	1 (1)	1 (1)	- (0)	- (0)	- (0)	1 (1)	1 (1)	- (0)
595	Chaenactis douglasii	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)
442	Chimaphila umbellata	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)
447	Clintonia uniflora	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
449	Coptis occidentalis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
602	Crepis accuminata	- (0)	2 (0)	- (0)	3 (1)	1 (1)	4 (0)	- (0)	- (0)	- (0)	1 (3)	1 (2)	- (0)
458	Dodecatheon jeffreyi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
455	Disporum trachycarpum	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	1 (0)	1 (0)	- (0)	- (0)
459	Epilobium angustifolium	- (0)	3 (1)	2 (1)	2 (1)	1 (1)	1 (1)	3 (0)	- (0)	1 (0)	5 (1)	4 (2)	- (0)
465	Fragaria vesca	- (0)	- (0)	- (0)	- (0)	- (0)	5 (1)	- (0)	- (0)	4 (9)	3 (5)	1 (1)	- (0)
466	Fragaria virginia	- (0)	+ (1)	- (0)	1 (1)	- (0)	2 (1)	- (0)	- (0)	- (0)	5 (6)	1 (0)	- (0)
471	Galium triflorum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (15)	- (0)	2 (3)	- (0)	- (0)	- (0)
620	Geranium richardsonii	- (0)	+ (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
473	Geranium viscosissimum	- (0)	+ (1)	1 (1)	4 (1)	- (0)	4 (1)	3 (1)	3 (4)	8 (4)	5 (3)	1 (0)	5 (1)
474	Geum triflorum	2 (1)	1 (1)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (1)	5 (1)
476	Goodyera oblongifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (0)	- (0)	- (0)	1 (1)	5 (1)
484	Hieracium albiflorum	- (0)	- (0)	- (0)	- (0)	- (0)	2 (1)	- (0)	- (0)	2 (1)	2 (1)	+ (1)	- (0)
486	Hieracium gracile	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
636	Lathyrus nevadensis	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
489	Ligusticum canbyi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
490	Ligusticum tenuifolium	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
497	Lomatium dissectum	- (0)	- (0)	- (0)	1 (8)	1 (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)
641	Lupinus argenteus	- (0)	+ (1)	- (0)	1 (1)	1 (15)	- (0)	- (0)	- (0)	- (0)	1 (1)	+ (1)	- (0)
642	Lupinus polyphyllus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
649	Mitella pentandra	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
502	Mitella stauropetala	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
505	Osmorhiza chilensis	- (0)	+ (1)	1 (1)	- (0)	- (0)	1 (3)	3 (3)	7 (2)	6 (1)	3 (1)	1 (1)	- (0)
653	Osmorhiza depauperata	- (0)	+ (1)	- (0)	1 (1)	2 (1)	- (0)	- (0)	1 (9)	- (0)	- (0)	+ (1)	- (0)
507	Pedicularis bracteosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
509	Pedicularis racemosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
514	Penstemon wilcoxii	- (0)	- (0)	- (0)	1 (1)	1 (1)	4 (1)	7 (2)	4 (2)	6 (1)	4 (1)	1 (1)	- (0)
663	Phacelia hastata	- (0)	- (0)	- (0)	1 (1)	2 (1)	2 (0)	3 (1)	- (0)	2 (1)	- (0)	1 (1)	- (0)
669	Potentilla diversifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	(0)
521	Potentilla flabellifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
670	Potentilla gracilis	2 (1)	- (0)	- (0)	- (0)	1 (1)	2 (1)	- (0)	- (0)	- (0)	1 (15)	1 (0)	- (0)
526	Pyrola asarifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
529	Pyrola secunda	- (0)	2 (2)	1 (1)	- (0)	1 (1)	- (0)	- (0)	1 (0)	- (0)	- (0)	1 (1)	- (0)
676	Saxifraga arguta	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
538	Senecio pseudaureus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
681	Senecio streptanthifolius	8 (1)	8 (1)	6 (4)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (3)	- (0)
539	Senecio triangularis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
542	Smilacina racemosa	- (0)	1 (1)	1 (1)	1 (1)	4 (1)	4 (8)	3 (1)	7 (8)	6 (5)	4 (1)	3 (1)	- (0)
543	Smilacina stellata	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	3 (3)	1 (3)	2 (1)	1 (1)	- (0)	- (0)
684	Solidago multiradiata	- (0)	3 (1)	5 (5)	- (0)	1 (3)	- (0)	- (0)	- (0)	- (0)	1 (1)	+ (1)	- (0)
546	Streptopus amplexifolius	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
547	Thalictrum occidentalis	- (0)	- (0)	- (0)	- (0)	1 (2)	2 (1)	3 (3)	6 (13)	8 (10)	4 (1)	2 (4)	- (0)
563	Trautvetteria caroliniensis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
560	Trillium ovatum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)
551	Valeriana sitchensis	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
552	Veratrum viride	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)
554	Viola adunca	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (1)	- (0)	2 (1)	2 (1)	3 (1)	1 (1)	- (0)
693	Viola nuttallii	- (0)	- (0)	- (0)	- (0)	2 (1)	2 (1)	3 (1)	1 (1)	- (0)	1 (0)	+ (1)	- (0)
557	Viola orbiculata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
694	Viola purpurea	- (0)	- (0)	- (0)	3 (1)	2 (1)	2 (1)	3 (15)	1 (2)	- (0)	3 (0)	1 (1)	- (0)
558	Xerophyllum tenax	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)	- (0)

APPENDIX C-1 (con)

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in central Idaho habitat types and phases.

ADP NUMBER	SPECIES	PSEUDOTSUGA MENZIESII SERIES (con)										PIEN SERIES	
		OSCH h.t.	SPBE h.t.			SYAL h.t.		ACGL h.t.		PHMA h.t.		CADI h.t	HYRE h.t.
			CARU Phase	SPBE Phase	PIPO Phase	SYAL Phase	PIPO Phase	SYOR Phase	ACGL Phase	PSME Phase	PIPO Phase		
		n= 7	n= 5	n= 9	n=25	n= 3	n=20	n= 5	n= 8	n=13	n=27	n= 7	n= 5
	TREES												
001	Abies grandis	1 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (0)	1 (3)	- (0)	- (0)
002	Abies lasiocarpa	- (0)	- (0)	2 (1)	+ (3)	3 (1)	- (0)	- (0)	2 (3)	- (0)	1 (1)	7 (5)	- (0)
006	Larix occidentalis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
007	Picea engelmannii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	10 (72)	10 (24)
009	Pinus albicaulis	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
010	Pinus contorta	- (0)	6 (6)	2 (9)	+ (3)	- (0)	2 (10)	- (0)	- (0)	- (0)	- (0)	3 (8)	- (0)
011	Pinus flexilis	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	8 (5)	- (0)	- (0)	- (0)	- (0)	10 (4)
013	Pinus ponderosa	1 (63)	- (0)	- (0)	10 (27)	- (0)	10 (30)	- (0)	5 (18)	- (0)	9 (19)	- (0)	- (0)
014	Populus tremuloides	- (0)	- (0)	- (0)	1 (19)	- (0)	2 (6)	- (0)	2 (26)	- (0)	+ (0)	3 (1)	- (0)
016	Pseudotsuga menziesii	10 (48)	10 (43)	10 (66)	10 (30)	10 (38)	10 (51)	10 (62)	10 (48)	10 (51)	10 (46)	1 (1)	10 (57)
	SHRUBS and SUBSHRUBS												
102	Acer glabrum	3 (2)	2 (1)	4 (5)	3 (2)	3 (15)	1 (1)	10 (13)	10 (17)	4 (2)	5 (6)	- (0)	2 (1)
104	Alnus sinuata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
105	Amelanchier alnifolia	6 (8)	4 (1)	7 (4)	10 (4)	3 (1)	8 (6)	2 (1)	10 (14)	8 (4)	10 (4)	- (0)	- (0)
201	Arctstaphylos uva-ursi	- (0)	- (0)	- (0)	- (0)	- (0)	2 (38)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
150	Artemisia tridentata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	+ (1)	- (0)	- (0)
203	Berberis repens	6 (11)	6 (1)	7 (12)	7 (1)	10 (6)	6 (2)	1 (1)	9 (4)	5 (3)	7 (4)	- (0)	- (0)
107	Ceanothus velutinus	1 (3)	- (0)	- (0)	5 (3)	- (0)	2 (7)	- (0)	- (0)	5 (2)	3 (3)	- (0)	- (0)
173	Cercocarpus ledifolius	[illegible] (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (3)	- (0)	1 (1)	- (0)	- (0)	- (0)
204	Clematis columbiana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	5 (6)	- (0)	2 (1)	- (0)	- (0)
205	Gaultheria humifusa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
111	Holodiscus discolor	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (3)	- (0)	- (0)
112	Juniperus communis	- (0)	2 (0)	2 (9)	- (0)	- (0)	- (0)	6 (2)	- (0)	- (0)	- (0)	- (0)	6 (3)
113	Ledum glandulosum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	4 (0)	- (0)
206	Linnaea borealis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (15)	- (0)
154	Lonicera caerulea	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
115	Lonicera utahensis	- (0)	2 (0)	- (0)	2 (2)	3 (1)	1 (1)	- (0)	4 (1)	- (0)	2 (2)	3 (1)	- (0)
116	Menziesia ferruginea	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
118	Pachistima myrsinites	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
122	Physocarpus malvaceus	- (0)	- (0)	- (0)	2 (1)	- (0)	2 (2)	- (0)	- (0)	10 (58)	10 (56)	- (0)	- (0)
124	Prunus virginiana	1 (63)	- (0)	4 (8)	4 (5)	3 (15)	5 (3)	2 (37)	5 (1)	5 (3)	3 (2)	- (0)	- (0)
125	Purshia tridentata	- (0)	- (0)	2 (1)	2 (11)	- (0)	2 (8)	- (0)	- (0)	3 (1)	1 (1)	- (0)	- (0)
128	Ribes cereum	1 (1)	6 (1)	6 (3)	+ (1)	7 (2)	3 (8)	10 (3)	4 (1)	3 (2)	- (0)	- (0)	- (0)
130	Ribes lacustre	- (0)	- (0)	- (0)	+ (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	7 (10)	- (0)
159	Ribes montigenum	- (0)	2 (3)	2 (1)	- (0)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	1 (15)	4 (8)
131	Ribes viscosissimum	- (0)	4 (1)	2 (1)	- (0)	- (0)	- (0)	2 (1)	2 (1)	1 (3)	1 (3)	- (0)	- (0)
133	Rosa gymnocarpa	- (0)	- (0)	1 (1)	1 (1)	- (0)	1 (2)	- (0)	- (0)	- (0)	4 (2)	1 (1)	- (0)
161	Rosa nutkana	- (0)	- (0)	- (0)	1 (1)	- (0)	3 (4)	2 (1)	- (0)	- (0)	1 (6)	- (0)	- (0)
134	Rosa woodsii	- (0)	- (0)	- (0)	2 (1)	- (0)	4 (2)	- (0)	- (0)	2 (1)	1 (2)	- (0)	- (0)
136	Rubus parviflorus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	4 (9)	- (0)	2 (6)	3 (2)	- (0)
137	Salix scouleriana	1 (1)	- (0)	- (0)	5 (3)	3 (1)	2 (3)	- (0)	1 (3)	2 (1)	3 (6)	- (0)	- (0)
139	Sheperdia canadensis	- (0)	- (0)	3 (1)	- (0)	- (0)	- (0)	6 (5)	- (0)	1 (0)	+ (3)	- (0)	6 (1)
140	Sorbus scopulina	- (0)	- (0)	2 (1)	2 (0)	- (0)	1 (1)	- (0)	4 (6)	- (0)	3 (0)	- (0)	- (0)
142	Spiraea betulifolia	1 (1)	10 (24)	9 (47)	9 (36)	3 (3)	8 (31)	- (0)	2 (3)	4 (17)	10 (14)	- (0)	- (0)
162	Spiraea pyramidata	- (0)	- (0)	1 (85)	2 (32)	- (0)	1 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
143	Symphoricarpos albus	[illegible] (0)	- (0)	- (0)	2 (2)	10 (11)	10 (41)	- (0)	1 (15)	2 (20)	6 (11)	- (0)	- (0)
163	Symphoricarpos oreophilus	[illegible] (10)	10 (7)	10 (11)	5 (5)	7 (2)	4 (2)	10 (12)	8 (1)	7 (5)	3 (2)	- (0)	6 (1)
144	Taxus brevifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
145	Vaccinium caespitosum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
146	Vaccinium globulare	- (0)	- (0)	- (0)	1 (0)	- (0)	1 (1)	- (0)	1 (15)	- (0)	1 (29)	- (0)	- (0)
148	Vaccinium scoparium	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)
	FERNS and FERN ALLIES												
253	Cystopteris fragilis	- (0)	- (0)	1 (1)	3 (0)	- (0)	2 (0)	- (0)	1 (3)	5 (3)	3 (1)	- (0)	- (0)
254	Equisetum arvense	- (0)	- (0)	- (0)	+ (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	7 (1)	- (0)
259	Pteridium aquilinum	- (0)	- (0)	- (0)	+ (3)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
	GRAMINOIDS												
301	Agropyron spicatum	- (0)	2 (1)	3 (7)	2 (4)	3 (1)	4 (2)	4 (2)	1 (1)	3 (1)	+ (3)	- (0)	- (0)
304	Bromus vulgaris	- (0)	- (0)	1 (3)	1 (1)	3 (1)	- (0)	- (0)	- (0)	1 (1)	2 (1)	- (0)	- (0)
305	Calamagrostis canadensis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	7 (5)	- (0)
307	Calamagrostis rubescens	1 (63)	10 (80)	3 (3)	6 (34)	10 (26)	8 (26)	- (0)	- (0)	2 (2)	6 (8)	1 (3)	- (0)
308	Carex concinnoides	- (0)	2 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)
339	Carex disperma	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	10 (33)	- (0)
309	Carex geyeri	9 (15)	8 (1)	6 (21)	8 (11)	7 (9)	9 (19)	- (0)	7 (14)	3 (2)	7 (16)	1 (1)	- (0)
311	Carex rossii	3 (0)	- (0)	1 (1)	3 (1)	- (0)	4 (1)	2 (1)	1 (1)	4 (1)	1 (1)	- (0)	- (0)
316	Elymus glaucus	1 (1)	- (0)	- (0)	1 (1)	- (0)	2 (1)	- (0)	1 (1)	1 (1)	1 (1)	1 (1)	- (0)
317	Festuca idahoensis	- (0)	2 (1)	2 (2)	1 (1)	3 (3)	4 (1)	- (0)	- (0)	2 (2)	+ (1)	- (0)	4 (1)
348	Hesperochloa kingii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	6 (1)	- (0)	1 (1)	- (0)	- (0)	- (0)
322	Juncus parryi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
323	Koeleria cristata	- (0)	- (0)	- (0)	+ (1)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
325	Luzula hitchcockii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
349	Melica bulbosa	1 (1)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	1 (1)	1 (0)	+ (1)	- (0)	- (0)
331	Poa nervosa	3 (1)	10 (1)	6 (1)	4 (1)	- (0)	2 (1)	6 (1)	4 (1)	4 (1)	3 (1)	- (0)	2 (1)
360	Stipa occidentalis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)

* Code to constancy values

+ = 0-5 %, 1 = 5-15%, 2 = 15-25%, 3 = 25-35%, 4 = 35-45%, 5 = 45-55%, 6 = 55-65%, 7 = 65-75%, 8 = 75-85%, 9 = 85-95%, 10 = 95-100%

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in central Idaho habitat types and phases.

ADP NUMBER	SPECIES	PSEUDOTSUGA MENZIESII SERIES (con)										PIEN SERIES (con)	
		OSCH h.t.	SPBE h.t.			SYAL h.t.		ACGL h.t.		PHMA h.t.		CADI h.t	HYRE h.t.
			CARU Phase	SPBE Phase	PIPO Phase	SYAL Phase	PIPO Phase	SYOR Phase	ACGL Phase	PSME Phase	PIPO Phase		
		n= 7	n= 5	n= 9	n=25	n= 3	n=20	n= 5	n= 8	n=13	n=27	n= 7	n= 5
	FORBS												
401	Achillaea millefollium	3 (1)	6 (1)	4 (1)	5 (1)	7 (1)	7 (1)	2 (1)	- (0)	2 (1)	3 (1)	- (0)	2 (1)
402	Actaea rubra	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	7 (4)	- (0)
565	Aconitum columbianum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
403	Adenocaulon bicolor	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	+ (3)	- (0)	- (0)
738	Antennaria corymbosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
414	Antennaria microphylla	- (0)	8 (1)	2 (2)	2 (0)	- (0)	3 (0)	6 (1)	- (0)	1 (1)	1 (0)	- (0)	4 (1)
413	Antennaria racemosa	- (0)	2 (1)	6 (2)	3 (1)	- (0)	1 (1)	- (0)	2 (1)	1 (0)	1 (18)	- (0)	- (0)
577	Arenaria aculeata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
420	Arenaria macrophylla	7 (8)	- (0)	2 (1)	7 (3)	- (0)	6 (1)	- (0)	8 (2)	2 (14)	8 (1)	- (0)	- (0)
421	Arnica cordifolia	6 (4)	8 (23)	4 (6)	8 (9)	7 (3)	6 (13)	6 (12)	9 (7)	8 (4)	9 (10)	7 (2)	8 (1)
422	Arnica latifolia	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
426	Aster conspicuus	3 (8)	2 (1)	1 (1)	4 (3)	3 (3)	3 (2)	- (0)	6 (1)	5 (10)	4 (1)	- (0)	- (0)
582	Aster engelmannii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
430	Astragalus miser	- (0)	- (0)	1 (15)	- (0)	- (0)	- (0)	2 (63)	- (0)	- (0)	- (0)	- (0)	4 (1)
431	Balsamorhiza sagittata	3 (0)	2 (1)	6 (4)	3 (1)	7 (1)	3 (3)	2 (1)	- (0)	2 (1)	1 (1)	- (0)	- (0)
696	Caltha biflora	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
741	Castilleja covilleana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)	- (0)	- (0)
438	Castilleja miniata	- (0)	4 (1)	3 (1)	1 (0)	3 (1)	1 (1)	6 (1)	- (0)	- (0)	1 (1)	- (0)	- (0)
595	Chaenactis douglasii	- (0)	- (0)	- (0)	+ (1)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
442	Chimaphila umbellata	- (0)	2 (1)	- (0)	3 (3)	- (0)	1 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)
447	Clintonia uniflora	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
449	Coptis occidentalis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
602	Crepis accuminata	- (0)	- (0)	- (0)	+ (1)	3 (1)	2 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)
458	Dodecatheon jeffreyi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
455	Disporum trachycarpum	- (0)	- (0)	- (0)	+ (1)	3 (1)	2 (1)	2 (1)	4 (1)	2 (2)	3 (1)	- (0)	- (0)
459	Epilobium angustifolium	1 (15)	2 (0)	1 (3)	3 (1)	3 (1)	4 (2)	2 (1)	1 (1)	2 (0)	3 (0)	9 (1)	2 (1)
465	Fragaria vesca	- (0)	4 (2)	1 (15)	5 (5)	3 (3)	7 (4)	- (0)	4 (14)	2 (2)	6 (4)	1 (1)	- (0)
466	Fragaria virginiana	- (0)	2 (1)	2 (8)	1 (1)	- (0)	3 (4)	- (0)	- (0)	1 (1)	+ (3)	4 (1)	- (0)
471	Galium triflorum	1 (1)	- (0)	- (0)	2 (1)	- (0)	1 (2)	- (0)	2 (1)	2 (0)	3 (5)	7 (4)	- (0)
620	Geranium richardsonii	- (0)	- (0)	- (0)	+ (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	1 (1)	- (0)
473	Geranium viscosissimum	3 (2)	- (0)	1 (3)	5 (3)	- (0)	4 (1)	- (0)	- (0)	1 (1)	2 (0)	- (0)	- (0)
474	Geum triflorum	- (0)	2 (1)	- (0)	- (0)	3 (3)	1 (1)	4 (1)	- (0)	1 (1)	- (0)	- (0)	- (0)
476	Goodyera oblongifolia	- (0)	2 (1)	1 (1)	1 (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	2 (1)	- (0)	- (0)
484	Hieracium albiflorum	1 (1)	- (0)	2 (3)	4 (1)	- (0)	2 (1)	2 (1)	2 (1)	- (0)	5 (1)	- (0)	- (0)
486	Hieracium gracile	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
636	Lathyrus nevadensis	- (0)	- (0)	- (0)	1 (1)	- (0)	2 (5)	- (0)	- (0)	- (0)	2 (4)	- (0)	- (0)
489	Ligusticum canbyi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
490	Ligusticum tenuifolium	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
497	Lomatium dissectum	1 (1)	- (0)	2 (1)	1 (2)	- (0)	- (0)	- (0)	- (0)	3 (0)	1 (1)	- (0)	- (0)
641	Lupinus argenteus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)
642	Lupinus polyphyllus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
649	Mitella pentandra	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	6 (2)	- (0)
502	Mitella stauropetala	- (0)	- (0)	- (0)	- (0)	- (0)	1 (0)	- (0)	- (0)	1 (1)	2 (1)	- (0)	- (0)
505	Osmorhiza chilensis	10 (21)	- (0)	1 (1)	2 (1)	3 (1)	2 (4)	- (0)	6 (2)	2 (3)	4 (1)	4 (1)	- (0)
653	Osmorhiza depauperata	- (0)	- (0)	- (0)	1 (1)	- (0)	1 (1)	- (0)	1 (1)	- (0)	1 (1)	6 (1)	- (0)
507	Pedicularis bracteosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)	- (0)	- (0)
509	Pedicularis racemosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
514	Penstemon wilcoxii	3 (1)	4 (1)	- (0)	4 (1)	7 (0)	3 (1)	- (0)	8 (1)	3 (1)	3 (0)	- (0)	- (0)
663	Phacelia hastata	- (0)	- (0)	- (0)	+ (1)	3 (1)	1 (1)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
669	Potentilla diversifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
521	Potentilla flabellifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
670	Potentilla gracilis	- (0)	- (0)	- (0)	+ (1)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
526	Pyrola asarifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	6 (1)	- (0)
529	Pyrola secunda	- (0)	- (0)	1 (1)	1 (2)	- (0)	1 (1)	2 (1)	1 (3)	1 (0)	1 (2)	10 (4)	6 (1)
676	Saxifraga arguta	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	7 (8)	- (0)
538	Senecio pseudaureus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
681	Senecio streptanthifolius	- (0)	- (0)	2 (2)	- (0)	- (0)	- (0)	10 (1)	- (0)	- (0)	- (0)	- (0)	6 (1)
539	Senecio triangularis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	7 (8)	- (0)
542	Smilacina racemosa	7 (8)	4 (1)	3 (2)	6 (2)	10 (5)	6 (3)	2 (3)	9 (8)	6 (4)	9 (1)	- (0)	- (0)
543	Smilacina stellata	- (0)	- (0)	- (0)	+ (1)	3 (0)	- (0)	- (0)	2 (1)	2 (2)	1 (2)	4 (2)	- (0)
684	Solidago multiradiata	- (0)	- (0)	1 (1)	- (0)	3 (1)	1 (1)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)
546	Streptopus amplexifolius	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	4 (1)	- (0)
547	Thalictrum occidentalis	3 (1)	- (0)	1 (15)	2 (1)	7 (20)	4 (6)	- (0)	6 (25)	1 (1)	4 (6)	6 (10)	- (0)
563	Trautvetteria caroliniensis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
560	Trillium ovatum	- (0)	- (0)	- (0)	- (0)	- (0)	3 (0)	- (0)	- (0)	- (0)	2 (1)	- (0)	- (0)
551	Valeriana sitchensis	1 (1)	- (0)	- (0)	1 (0)	- (0)	- (0)	- (0)	2 (15)	- (0)	1 (1)	- (0)	- (0)
552	Veratrum viride	- (0)	- (0)	- (0)	+ (1)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
554	Viola adunca	- (0)	- (0)	- (0)	+ (0)	- (0)	4 (1)	- (0)	2 (1)	- (0)	1 (1)	- (0)	- (0)
693	Viola nuttallii	4 (1)	- (0)	- (0)	+ (1)	- (0)	1 (1)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)
557	Viola orbiculata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)
694	Viola purpurea	- (0)	- (0)	- (0)	+ (1)	- (0)	- (0)	- (0)	- (0)	1 (1)	+ (1)	- (0)	- (0)
558	Xerophyllum tenax	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)

APPENDIX C-1 (con)

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in central Idaho habitat types and phases.

ADP NUMBER	SPECIES	ABIES GRANDIS SERIES: CARU h.t	SPBE h.t	VAGL h.t	ACGL h.t.: PHMA Phase	ACGL h.t.: ACGL Phase	LIBO h.t.: VAGL Phase	LIBO h.t.: LIBO Phase	VACA h.t.	CLUN h.t.	ABIES LASIOCARPA SERIES: CABI h.t.	CACA h.t.: CACA Phase	CACA h.t.: VACA Phase	CACA h.t.: LICA Phase	CACA h.t.: LEGL Phase
		n= 7	n= 8	n-12	n=12	n=14	n= 4	n= 4	n= 8	n=15	n= 8	n= 7	n= 8	n=14	n=11
	TREES														
001	Abies grandis	10 (41)	10 (40)	10 (44)	10 (44)	10 (65)	10 (44)	10 (51)	10 (14)	10 (47)	- (0)	- (0)	1 (1)	- (0)	2 (1)
002	Abies lasiocarpa	1 (1)	- (0)	6 (16)	1 (37)	1 (3)	3 (37)	- (0)	8 (3)	1 (15)	10 (37)	9 (10)	9 (21)	10 (35)	9 (35)
006	Larix occidentalis	- (0)	3 (2)	3 (15)	2 (2)	1 (8)	- (0)	3 (0)	3 (8)	5 (9)	- (0)	- (0)	- (0)	- (0)	- (0)
007	Picea engelmannii	1 (1)	1 (1)	7 (20)	1 (15)	1 (3)	10 (14)	3 (1)	5 (1)	9 (27)	10 (34)	10 (33)	10 (8)	10 (33)	10 (30)
009	Pinus albicaulis	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (1)
010	Pinus contorta	6 (13)	- (0)	7 (15)	1 (0)	- (0)	5 (3)	5 (1)	10 (44)	2 (5)	4 (2)	9 (25)	10 (38)	7 (16)	8 (9)
011	Pinus flexilis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
013	Pinus ponderosa	7 (7)	9 (26)	3 (7)	6 (16)	5 (12)	5 (2)	5 (19)	1 (15)	4 (9)	- (0)	- (0)	- (0)	- (0)	- (0)
014	Populus tremuloides	- (0)	3 (9)	1 (1)	- (0)	- (0)	- (0)	- (0)	5 (11)	- (0)	1 (3)	- (0)	3 (20)	1 (0)	- (0)
016	Pseudotsuga menziesii	10 (26)	10 (17)	7 (31)	10 (21)	9 (16)	8 (3)	8 (18)	9 (13)	8 (19)	- (0)	1 (1)	1 (1)	1 (1)	4 (1)
	SHRUBS and SUBSHRUBS														
102	Acer glabrum	- (0)	4 (1)	2 (2)	5 (2)	10 (21)	5 (1)	5 (3)	- (0)	5 (16)	- (0)	- (0)	- (0)	- (0)	- (0)
104	Alnus sinuata	- (0)	- (0)	2 (15)	- (0)	- (0)	- (0)	3 (1)	- (0)	2 (23)	3 (2)	1 (1)	- (0)	1 (3)	1 (3)
105	Amelanchier alnifolia	7 (3)	6 (2)	8 (2)	7 (3)	8 (7)	10 (1)	10 (5)	5 (2)	9 (3)	- (0)	1 (1)	1 (3)	3 (5)	- (0)
201	Arctstaphylos uva-ursi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)
150	Artemisia tridentata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
203	Berberis repens	3 (1)	3 (2)	2 (1)	5 (1)	2 (0)	3 (1)	- (0)	1 (1)	1 (1)	- (0)	3 (1)	- (0)	- (0)	- (0)
107	Ceanothus velutinus	3 (2)	5 (1)	1 (3)	6 (4)	1 (1)	5 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
173	Cercocarpus ledifolius	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
204	Clematis columbiana	- (0)	1 (3)	2 (1)	2 (1)	2 (1)	3 (3)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
205	Gaultheria humifusa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (1)	- (0)	1 (1)	1 (0)	5 (7)
111	Holodiscus discolor	1 (1)	- (0)	- (0)	2 (2)	1 (8)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
112	Juniperus communis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (0)
113	Ledum glandulosum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	5 (8)	- (0)	3 (1)	- (0)	10 (47)
206	Linnaea borealis	- (0)	- (0)	- (0)	1 (1)	1 (1)	10 (41)	10 (15)	1 (1)	6 (17)	- (0)	- (0)	3 (8)	1 (8)	3 (18)
154	Lonicera caerulea	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	3 (2)	8 (4)	- (0)	2 (1)
115	Lonicera utahensis	6 (1)	4 (14)	10 (9)	7 (8)	7 (5)	10 (5)	8 (3)	8 (2)	10 (9)	3 (8)	1 (3)	1 (1)	6 (3)	5 (1)
116	Menziesia ferruginea	- (0)	- (0)	- (0)	- (0)	- (0)	3 (85)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	1 (1)	2 (31)
118	Pachistima myrsinites	- (0)	- (0)	1 (3)	2 (50)	- (0)	- (0)	3 (3)	1 (1)	1 (15)	- (0)	- (0)	- (0)	- (0)	- (0)
122	Physocarpus malvaceus	- (0)	- (0)	2 (2)	10 (25)	7 (10)	3 (1)	5 (8)	- (0)	1 (3)	- (0)	- (0)	- (0)	- (0)	- (0)
124	Prunus virginiana	- (0)	1 (1)	- (0)	1 (1)	3 (2)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
125	Purshia tridentata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
128	Ribes cereum	1 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	3 (1)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)
130	Ribes lacustre	- (0)	1 (1)	2 (1)	2 (2)	2 (1)	5 (2)	3 (1)	- (0)	6 (4)	4 (2)	7 (1)	1 (0)	5 (1)	2 (8)
159	Ribes montigenum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)	- (0)	1 (3)	- (0)
131	Ribes viscosissimum	1 (0)	1 (1)	3 (2)	3 (1)	5 (1)	5 (2)	- (0)	- (0)	5 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
133	Rosa gymnocarpa	3 (1)	8 (5)	7 (1)	9 (4)	9 (2)	10 (2)	10 (2)	1 (3)	9 (3)	- (0)	- (0)	1 (3)	1 (1)	- (0)
161	Rosa nutkana	- (0)	1 (3)	- (0)	- (0)	- (0)	3 (1)	- (0)	1 (1)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
134	Rosa woodsii	- (0)	1 (1)	2 (1)	- (0)	1 (1)	3 (1)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)	- (0)	- (0)
136	Rubus parviflorus	1 (1)	3 (1)	5 (2)	6 (6)	6 (5)	8 (1)	5 (2)	- (0)	9 (4)	- (0)	- (0)	- (0)	- (0)	1 (1)
137	Salix scouleriana	6 (2)	8 (1)	5 (4)	7 (10)	3 (1)	3 (1)	3 (1)	- (0)	4 (1)	- (0)	3 (2)	- (0)	1 (2)	1 (0)
139	Sheperdia canadensis	- (0)	- (0)	3 (1)	1 (1)	- (0)	3 (3)	- (0)	1 (3)	1 (3)	- (0)	- (0)	1 (1)	- (0)	3 (2)
140	Sorbus scopulina	3 (1)	1 (3)	6 (2)	3 (1)	6 (4)	3 (1)	5 (1)	6 (1)	8 (1)	- (0)	1 (1)	- (0)	6 (0)	- (0)
142	Spiraea betulifolia	9 (2)	8 (20)	8 (4)	8 (10)	6 (4)	10 (1)	8 (1)	5 (2)	5 (5)	- (0)	- (0)	- (0)	1 (2)	1 (1)
162	Spiraea pyramidata	- (0)	3 (39)	- (0)	1 (15)	- (0)	- (0)	- (0)	1 (15)	- (0)	- (0)	- (0)	3 (19)	- (0)	2 (2)
143	Symphoricarpos albus	4 (1)	6 (7)	- (0)	7 (8)	6 (6)	- (0)	5 (1)	5 (2)	3 (4)	- (0)	- (0)	- (0)	- (0)	- (0)
163	Symphoricarpos oreophilus	3 (2)	1 (1)	2 (1)	1 (3)	1 (9)	- (0)	- (0)	- (0)	1 (1)	- (0)	1 (3)	- (0)	1 (3)	- (0)
144	Taxus brevifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)	- (0)	- (0)	- (0)	- (0)
145	Vaccinium caespitosum	- (0)	- (0)	- (0)	- (0)	- (0)	3 (37)	- (0)	10 (47)	- (0)	4 (1)	1 (1)	10 (19)	1 (1)	2 (8)
146	Vaccinium globulare	4 (1)	3 (2)	10 (60)	5 (14)	5 (14)	8 (23)	10 (2)	- (0)	9 (27)	3 (2)	- (0)	- (0)	8 (7)	1 (3)
148	Vaccinium scoparium	(0)	- (0)	1 (1)	- (0)	- (0)	3 (1)	- (0)	1 (1)	1 (1)	9 (6)	4 (5)	6 (3)	6 (10)	10 (39)
	FERNS and FERN ALLIES														
253	Cystopteris fragilis	- (0)	- (0)	- (0)	2 (1)	1 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	1 (1)	- (0)	- (0)	- (0)
254	Equisetum arvense	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	4 (2)	3 (1)	4 (1)	1 (2)	3 (1)
259	Pteridium aquilinum	- (0)	- (0)	1 (1)	2 (1)	1 (1)	- (0)	3 (1)	- (0)	1 (3)	- (0)	- (0)	- (0)	1 (1)	- (0)
	GRAMINOIDS														
301	Agropyron spicatum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
304	Bromus vulgaris	1 (3)	1 (1)	5 (1)	3 (1)	6 (4)	5 (1)	10 (1)	- (0)	9 (2)	- (0)	- (0)	- (0)	2 (1)	1 (1)
305	Calamagrostis canadensis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (1)	6 (4)	10 (62)	9 (51)	10 (26)	6 (10)
307	Calamagrostis rubescens	10 (48)	9 (14)	6 (5)	8 (11)	4 (3)	8 (2)	5 (15)	10 (32)	4 (3)	- (0)	4 (2)	- (0)	- (0)	3 (1)
308	Carex concinnoides	3 (1)	- (0)	1 (1)	1 (1)	- (0)	8 (1)	5 (1)	1 (1)	3 (2)	- (0)	- (0)	- (0)	- (0)	3 (1)
339	Carex disperma	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	1 (3)	- (0)	1 (1)	2 (2)
309	Carex geyeri	10 (5)	6 (3)	7 (3)	7 (1)	6 (2)	8 (1)	5 (0)	8 (23)	3 (10)	4 (6)	1 (1)	1 (1)	- (0)	4 (1)
311	Carex rossii	6 (1)	4 (1)	8 (1)	5 (1)	6 (0)	3 (1)	3 (1)	4 (1)	6 (1)	4 (1)	4 (1)	4 (2)	4 (2)	- (0)
316	Elymus glaucus	1 (3)	1 (1)	- (0)	1 (1)	- (0)	- (0)	- (0)	3 (1)	1 (2)	- (0)	3 (1)	1 (1)	4 (1)	- (0)
317	Festuca idahoensis	1 (1)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)	- (0)	1 (1)	1 (1)	- (0)	- (0)
348	Hesperochloa kingii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
322	Juncus parryi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
323	Koeleria cristata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
325	Luzula hitchcockii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (8)	- (0)
349	Melica bulbosa	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
331	Poa nervosa	1 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (1)	3 (1)	- (0)	- (0)
360	Stipa occidentalis	4 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (1)	- (0)	- (0)	- (0)	- (0)	1 (0)	- (0)

* Code to constancy values: + = 0-5 %; 1 = 5-15%; 2 = 15-25%; 3 = 25-35%; 4 = 35-45%; 5 = 45-55%; 6 = 55-65%; 7 = 65-75%; 8 = 75-85%; 9 = 85-95%; 10 = 95-100%

APPENDIX C-1 (con)

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in central Idaho habitat types and phases.

ADP NUMBER	SPECIES	ABIES GRANDIS SERIES (con)									ABIES LASIOCARPA SERIES (con)				
		CARU h.t	SPBE h.t	VAGL h.t	ACGL h.t.		LIBO h.t.		VACA h.t.	CLUN h.t.	CABI h.t.	CACA h.t.			
					PHMA Phase	ACGL Phase	VAGL Phase	LIBO Phase				CACA Phase	VACA Phase	LICA Phase	LEGL Phase
	FORBS	n= 7	n= 8	n=12	n=12	n=14	n= 4	n= 4	n= 8	n=15	n= 8	n= 7	n= 8	n=14	n=11
401	Achillaea millefollium	6 (1)	4 (0)	1 (1)	- (0)	- (0)	- (0)	3 (1)	6 (1)						
402	Actaea rubra	- (0)	- (0)	1 (15)	1 (1)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	1 (15)	- (0)	1 (1)	- (0)
565	Aconitum columbianum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	9 (9)	3 (1)	9 (2)	6 (7)	1 (1)
403	Adenocaulon bicolor	- (0)	1 (3)	- (0)	4 (6)	5 (7)	3 (15)	5 (2)	- (0)	5 (2)	- (0)	- (0)	- (0)	- (0)	- (0)
738	Antennaria corymbosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	4 (1)	- (0)	- (0)
414	Antennaria microphylla	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	3 (0)	4 (1)	- (0)	- (0)	3 (1)	- (0)	- (0)	- (0)
413	Antennaria racemosa	- (0)	- (0)	2 (1)	- (0)	2 (1)	3 (1)	5 (2)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)
577	Arenaria aculeata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
420	Arenaria macrophylla	7 (1)	9 (3)	8 (1)	8 (1)	9 (1)	10 (1)	10 (1)	1 (1)	9 (3)	3 (8)	1 (1)	- (0)	5 (1)	- (0)
421	Arnica cordifolia	9 (1)	8 (15)	9 (3)	7 (11)	5 (13)	8 (2)	10 (1)	- (0)	5 (3)	3 (1)	4 (1)	- (0)	2 (1)	5 (16)
422	Arnica latifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	1 (1)	2 (1)	2 (9)
426	Aster conspicuus	- (0)	6 (2)	6 (1)	5 (1)	4 (1)	3 (1)	3 (1)	- (0)	4 (3)	- (0)	- (0)	- (0)	- (0)	- (0)
582	Aster engelmannii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)
430	Astragalus miser	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
431	Balsamorhiza sagittata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
696	Caltha biflora	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	10 (21)	- (0)	1 (1)	- (0)	- (0)
741	Castilleja covilleana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
438	Castilleja miniata	- (0)	3 (1)	- (0)	2 (1)	1 (1)	- (0)	- (0)	1 (3)	1 (1)	- (0)	1 (1)	3 (1)	1 (1)	- (0)
595	Chaenactis douglasii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
442	Chimaphila umbellata	7 (1)	8 (10)	8 (2)	8 (3)	8 (4)	10 (5)	10 (5)	8 (4)	9 (4)	- (0)	- (0)	- (0)	4 (1)	1 (0)
447	Clintonia uniflora	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	10 (6)	- (0)	- (0)	- (0)	1 (1)	- (0)
449	Coptis occidentalis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (1)	- (0)	3 (23)	- (0)	- (0)	1 (1)	1 (1)	3 (1)
602	Crepis accuminata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
458	Dodecatheon jeffreyi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	10 (21)	1 (3)	5 (1)	6 (10)	5 (3)
455	Disporum trachycarpum	- (0)	- (0)	- (0)	4 (1)	6 (1)	5 (0)	5 (1)	- (0)	7 (1)	- (0)	1 (1)	- (0)	1 (1)	- (0)
459	Epilobium angustifolium	3 (1)	4 (1)	3 (2)	2 (0)	1 (1)	3 (1)	- (0)	8 (1)	1 (1)	6 (2)	9 (1)	10 (1)	4 (2)	5 (1)
465	Fragaria vesca	6 (2)	5 (1)	7 (1)	9 (1)	7 (2)	5 (1)	10 (2)	1 (3)	9 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)
466	Fragaria virginiana	1 (1)	3 (2)	4 (1)	- (0)	1 (1)	5 (0)	3 (1)	10 (17)	3 (1)	4 (1)	9 (7)	10 (8)	1 (3)	4 (2)
471	Galium triflorum	3 (1)	4 (1)	6 (1)	5 (1)	9 (2)	8 (1)	3 (1)	3 (1)	9 (4)	- (0)	3 (8)	3 (1)	4 (3)	- (0)
620	Geranium richardsonii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (1)	- (0)
473	Geranium viscosissimum	6 (1)	3 (1)	3 (1)	1 (3)	2 (1)	3 (1)	3 (1)	5 (1)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
474	Geum triflorum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	1 (3)	- (0)
476	Goodyera oblongifolia	1 (1)	6 (3)	7 (1)	6 (1)	9 (1)	8 (1)	8 (1)	3 (1)	8 (1)	- (0)	- (0)	- (0)	1 (1)	2 (1)
484	Hieracium albiflorum	6 (1)	4 (1)	5 (1)	7 (1)	5 (1)	5 (1)	8 (1)	8 (1)	4 (1)	- (0)	- (0)	1 (1)	4 (1)	- (0)
486	Hieracium gracile	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (0)	1 (1)
636	Lathyrus nevadensis	1 (1)	6 (13)	1 (1)	- (0)	4 (11)	2 (1)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
489	Ligusticum canbyi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	4 (5)	- (0)	1 (3)	6 (18)	2 (8)
490	Ligusticum tenuifolium	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	8 (17)	- (0)	2 (1)
497	Lomatium dissectum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
641	Lupinus argenteus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	1 (3)	1 (1)	1 (3)	- (0)	2 (2)
642	Lupinus polyphyllus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	4 (2)	3 (2)
649	Mitella pentandra	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	8 (3)	3 (1)	3 (1)	2 (1)	3 (1)
502	Mitella stauropetala	- (0)	- (0)	1 (1)	1 (1)	4 (1)	3 (0)	5 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)
505	Osmorhiza chilensis	9 (1)	6 (0)	7 (1)	7 (1)	10 (2)	8 (1)	10 (0)	6 (1)	9 (1)	4 (5)	1 (3)	4 (1)	7 (4)	- (0)
653	Osmorhiza depauperata	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (2)	6 (1)	1 (1)	- (0)	4 (1)
507	Pedicularis bracteosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	9 (0)	- (0)	3 (1)	6 (1)	2 (1)
509	Pedicularis racemosa	- (0)	1 (0)	3 (1)	2 (1)	1 (1)	3 (3)	5 (1)	- (0)	4 (4)	3 (1)	- (0)	- (0)	4 (1)	- (0)
514	Penstemon wilcoxii	3 (1)	3 (1)	- (0)	3 (0)	3 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
663	Phacelia hastata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
669	Potentilla diversifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
521	Potentilla flabellifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	5 (2)	3 (1)	3 (8)	4 (5)	1 (3)
670	Potentilla gracilis	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	6 (1)	- (0)	1 (3)	3 (2)	5 (1)	- (0)	- (0)
526	Pyrola asarifolia	- (0)	- (0)	2 (2)	- (0)	- (0)	5 (2)	3 (1)	- (0)	3 (2)	4 (1)	3 (0)	3 (1)	2 (7)	3 (1)
529	Pyrola secunda	6 (1)	5 (1)	8 (1)	5 (1)	6 (1)	5 (1)	8 (1)	4 (1)	9 (1)	4 (1)	4 (1)	1 (1)	5 (3)	5 (1)
676	Saxifraga arguta	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	9 (7)	- (0)	- (0)	- (0)	2 (1)
538	Senecio pseudaureus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	9 (0)	1 (1)	- (0)	- (0)
681	Senecio streptanthifolius	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
539	Senecio triangularis	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	9 (4)	1 (1)	1 (1)	7 (4)	4 (1)
542	Smilacina racemosa	7 (1)	5 (1)	6 (1)	7 (1)	9 (1)	5 (1)	5 (1)	- (0)	7 (2)	- (0)	3 (1)	1 (1)	1 (1)	- (0)
543	Smilacina stellata	1 (0)	1 (1)	1 (1)	2 (1)	2 (2)	3 (1)	- (0)	3 (1)	7 (1)	- (0)	9 (2)	5 (1)	2 (1)	1 (3)
684	Solidago multiradiata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (1)	1 (3)	- (0)	- (0)
546	Streptopus amplexifolius	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	5 (5)	3 (1)	1 (1)	5 (2)	3 (5)
547	Thalictrum occidentalis	6 (2)	8 (15)	9 (8)	8 (2)	9 (10)	10 (2)	8 (6)	6 (4)	9 (5)	3 (8)	7 (11)	6 (4)	8 (4)	4 (1)
563	Trautvetteria caroliniensis	- (0)	- (0)	1 (1)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (1)	5 (11)	1 (0)
560	Trillium ovatum	6 (1)	4 (1)	8 (1)	7 (1)	6 (1)	5 (1)	8 (1)	5 (1)	9 (1)	1 (1)	- (0)	3 (1)	6 (1)	3 (1)
551	Valeriana sitchensis	3 (2)	1 (1)	5 (1)	- (0)	3 (2)	3 (3)	3 (1)	1 (1)	4 (1)	5 (5)	1 (1)	1 (1)	6 (2)	5 (1)
552	Veratrum viride	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (15)	- (0)	1 (1)	6 (2)	1 (1)
554	Viola adunca	6 (1)	3 (1)	4 (1)	3 (0)	6 (1)	5 (1)	8 (1)	5 (1)	5 (1)	- (0)	4 (1)	4 (1)	1 (0)	- (0)
693	Viola nuttallii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
557	Viola orbiculata	- (0)	- (0)	6 (4)	1 (3)	1 (2)	5 (2)	10 (5)	3 (2)	9 (4)	1 (1)	1 (1)	- (0)	5 (1)	5 (1)
694	Viola purpurea	1 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
558	Xerophyllum tenax	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	6 (1)	5 (18)

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in central Idaho habitat types and phases.

ADP NUMBER	SPECIES	ABIES LASIOCARPA SERIES (con)											
		STAM h.t.		CLUN h.t.	MEFE h.t.	ACGL h.t.	VACA h.t.	LIBO h.t.	XETE h.t.			VAGL h.t.	SPBE h.t.
		LICA Phase	STAM Phase						LUHI Phase	VASC Phase	VAGL Phase		
		n=11	n= 7	n= 3	n= 8	n =5	n=13	n= 4	n=5	n= 6	n= 9	n=11	n= 7
	TREES												
001	Abies grandis	1 (15)	- (0)	3 (3)	3 (2)	- (0)	1 (1)	5 (2)	- (0)	- (0)	- (0)	2 (0)	- (0)
002	Abies lasiocarpa	10 (23)	10 (10)	10 (23)	10 (19)	10 (41)	9 (12)	10 (33)	10 (53)	10 (40)	10 (46)	10 (32)	10 (23)
006	Larix occidentalis	1 (1)	- (0)	3 (63)	4 (7)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
007	Picea engelmannii	10 (32)	10 (59)	10 (33)	10 (38)	- (0)	5 (7)	10 (25)	2 (37)	7 (9)	8 (14)	6 (17)	1 (1)
009	Pinus albicaulis	- (0)	- (0)	- (0)	- (0)	- (0)	2 (2)	3 (1)	8 (4)	3 (8)	1 (3)	1 (1)	1 (1)
010	Pinus contorta	5 (8)	3 (20)	7 (1)	5 (8)	- (0)	10 (58)	8 (23)	6 (2)	10 (14)	7 (11)	5 (4)	9 (10)
011	Pinus flexilis	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
013	Pinus ponderosa	- (0)	- (0)	3 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (8)	1 (3)
014	Populus tremuloides	- (0)	- (0)	- (0)	- (0)	2 (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)
016	Pseudotsuga menziesii	1 (1)	1 (3)	10 (14)	4 (3)	10 (27)	3 (8)	10 (11)	- (0)	2 (3)	4 (23)	9 (28)	9 (50)
	SHRUBS and SUBSHRUBS												
102	Acer glabrum	2 (1)	- (0)	3 (3)	- (0)	10 (14)	- (0)	- (0)	- (0)	- (0)	- (0)	5 (1)	3 (2)
104	Alnus sinuata	2 (3)	- (0)	7 (2)	4 (30)	- (0)	- (0)	3 (37)	- (0)	- (0)	1 (1)	1 (0)	- (0)
105	Amelanchier alnifolia	- (0)	1 (1)	10 (1)	1 (15)	8 (1)	2 (1)	- (0)	- (0)	- (0)	2 (0)	4 (2)	7 (4)
201	Arctostaphylos uva-ursi	- (0)	- (0)	- (0)	- (0)	- (0)	2 (8)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
150	Artemisia tridentata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
203	Berberis repens	- (0)	1 (1)	- (0)	- (0)	6 (1)	- (0)	- (0)	- (0)	- (0)	3 (1)	1 (1)	6 (5)
107	Ceanothus velutinus	- (0)	- (0)	3 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)
173	Cercocarpus ledifolius	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
204	Clematis columbiana	- (0)	- (0)	3 (1)	- (0)	8 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)
205	Gaultheria humifusa	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
111	Holodiscus discolor	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
112	Juniperus communis	- (0)	- (0)	- (0)	- (0)	- (0)	2 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
113	Ledum glandulosum	- (0)	1 (3)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	2 (1)	1 (3)	- (0)	- (0)
206	Linnaea borealis	1 (15)	1 (3)	7 (9)	4 (23)	- (0)	- (0)	10 (59)	- (0)	- (0)	- (0)	- (0)	- (0)
154	Lonicera caerulea	- (0)	- (0)	- (0)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
115	Lonicera utahensis	5 (0)	1 (1)	10 (14)	5 (2)	6 (6)	4 (4)	10 (5)	10 (1)	5 (1)	8 (2)	10 (15)	4 (2)
116	Menziesia ferruginea	2 (3)	- (0)	- (0)	10 (65)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (2)	- (0)	- (0)
118	Pachistima myrsinites	1 (1)	- (0)	3 (37)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
122	Physocarpus malvaceus	- (0)	- (0)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)
124	Prunus virginiana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
125	Purshia tridentata	- (0)	- (0)	- (0)	- (0)	- (0)	2 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
128	Ribes cereum	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (0)
130	Ribes lacustre	5 (1)	10 (4)	7 (2)	6 (1)	6 (1)	- (0)	8 (1)	2 (1)	2 (1)	1 (3)	4 (1)	- (0)
159	Ribes montigenum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
131	Ribes viscosissimum	- (0)	- (0)	7 (0)	1 (1)	6 (1)	- (0)	- (0)	- (0)	2 (0)	1 (1)	2 (1)	4 (1)
133	Rosa gymnocarpa	1 (1)	1 (1)	3 (15)	3 (3)	4 (1)	- (0)	5 (2)	- (0)	- (0)	1 (1)	5 (3)	- (0)
161	Rosa nutkana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
134	Rosa woodsii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)
136	Rubus parviflorus	1 (3)	3 (0)	7 (3)	5 (2)	2 (1)	- (0)	5 (2)	- (0)	- (0)	1 (0)	4 (5)	- (0)
137	Salix scouleriana	- (0)	- (0)	- (0)	- (0)	4 (1)	1 (15)	3 (0)	- (0)	- (0)	1 (1)	2 (2)	3 (2)
139	Sheperdia canadensis	- (0)	- (0)	- (0)	1 (15)	- (0)	4 (2)	5 (1)	- (0)	- (0)	- (0)	2 (1)	4 (2)
140	Sorbus scopulina	4 (1)	1 (3)	10 (0)	3 (0)	10 (2)	1 (1)	3 (1)	- (0)	- (0)	6 (1)	6 (2)	6 (1)
142	Spiraea betulifolia	2 (1)	- (0)	- (0)	4 (1)	2 (1)	1 (1)	5 (2)	- (0)	- (0)	7 (2)	5 (2)	10 (52)
162	Spiraea pyramidata	- (0)	1 (1)	- (0)	- (0)	- (0)	4 (2)	3 (3)	- (0)	- (0)	- (0)	1 (1)	- (0)
143	Symphoricarpos albus	2 (1)	- (0)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (1)	- (0)
163	Symphoricarpos oreophilus	- (0)	1 (1)	- (0)	1 (1)	8 (2)	- (0)	- (0)	- (0)	- (0)	1 (3)	3 (1)	4 (5)
144	Taxus brevifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
145	Vaccinium caespitosum	1 (1)	- (0)	- (0)	- (0)	- (0)	10 (42)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
146	Vaccinium globulare	8 (8)	4 (22)	10 (11)	8 (18)	- (0)	7 (43)	8 (14)	6 (1)	5 (1)	9 (41)	10 (48)	- (0)
148	Vaccinium scoparium	5 (1)	6 (1)	- (0)	4 (6)	- (0)	7 (13)	8 (1)	10 (39)	10 (40)	4 (11)	3 (5)	- (0)
	FERNS and FERN ALLIES												
253	Cystopteris fragilis	- (0)	- (0)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
254	Equisetum arvense	3 (1)	1 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)
259	Pteridium aquilinum	- (0)	- (0)	3 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)
	GRAMINOIDS												
301	Agropyron spicatum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
304	Bromus vulgaris	4 (10)	- (0)	7 (1)	4 (1)	- (0)	- (0)	- (0)	- (0)	2 (1)	2 (1)	6 (1)	- (0)
305	Calamagrostis canadensis	4 (0)	1 (1)	- (0)	- (0)	- (0)	3 (2)	3 (1)	2 (1)	2 (3)	3 (1)	- (0)	- (0)
307	Calamagrostis rubescens	2 (1)	1 (1)	3 (3)	3 (9)	- (0)	8 (30)	8 (14)	- (0)	5 (1)	4 (2)	5 (14)	6 (5)
308	Carex concinnoides	- (0)	1 (0)	- (0)	3 (1)	- (0)	4 (2)	10 (1)	2 (1)	- (0)	3 (1)	1 (1)	- (0)
339	Carex disperma	- (0)	4 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
309	Carex geyeri	3 (0)	1 (1)	3 (3)	3 (1)	8 (2)	9 (8)	5 (1)	6 (6)	7 (2)	3 (2)	7 (4)	7 (20)
311	Carex rossii	3 (0)	4 (1)	10 (1)	3 (1)	6 (1)	5 (1)	5 (1)	6 (1)	5 (1)	8 (1)	5 (1)	1 (1)
316	Elymus glaucus	2 (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	2 (0)	- (0)	2 (1)	- (0)	1 (1)
317	Festuca idahoensis	- (0)	- (0)	- (0)	- (0)	- (0)	2 (2)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
348	Hesperochloa kingii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
322	Juncus parryi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
323	Koeleria cristata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
325	Luzula hitchcockii	5 (3)	- (0)	- (0)	3 (0)	- (0)	- (0)	- (0)	10 (3)	3 (1)	3 (21)	1 (1)	- (0)
349	Melica bulbosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)
331	Poa nervosa	- (0)	- (0)	- (0)	- (0)	- (0)	2 (2)	- (0)	- (0)	3 (0)	- (0)	- (0)	3 (1)
360	Stipa occidentalis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)

*Code to constancy values: + = 0-5 %, 1 = 5-15%, 2 = 15-25%, 3 = 25-35%, 4 = 35-45%, 5 = 45-55%, 6 = 55-65%, 7 = 65-75%, 8 = 75-85%, 9 = 85-95%, 10 = 95-100%

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in central Idaho habitat types and phases.

ADP NUMBER	SPECIES	ABIES LASIOCARPA SERIES (con) STAM h.t. LICA Phase	STAM h.t. STAM Phase	CLUN h.t.	MEFE h.t.	ACGL h.t.	VACA h.t.	LIBO h.t.	XETE h.t. LUHI Phase	XETE h.t. VASC Phase	XETE h.t. VAGL Phase	VAGL h.t.	SPBE h.t.
	FORBS	n=11	n= 7	n= 3	n= 8	n =5	n=13	n= 4	n=5	n= 6	n= 9	n=11	n= 7
401	Achillaea millefollium	2 (1)	3 (1)	- (0)	- (0)	- (0)	7 (1)	- (0)	- (0)	2 (1)	(0)	1 (1)	1 (1)
402	Actaea rubra	- (0)	4 (1)	3 (1)	- (0)	2 (1)	- (0)	3 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)
565	Aconitum columbianum	6 (2)	4 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	1 (1)	1 (1)	- (0)
403	Adenocaulon bicolor	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)
738	Antennaria corymbosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
414	Antennaria microphylla	1 (1)	- (0)	- (0)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
413	Antennaria racemosa	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	3 (1)	- (0)	- (0)	1 (1)	- (0)	1 (3)
577	Arenaria aculeata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
420	Arenaria macrophylla	5 (0)	1 (1)	7 (2)	6 (0)	10 (4)	2 (1)	5 (8)	- (0)	3 (1)	8 (1)	9 (1)	3 (1)
421	Arnica cordifolia	5 (3)	7 (5)	3 (3)	6 (12)	4 (8)	3 (2)	8 (6)	- (0)	2 (1)	4 (1)	7 (3)	9 (4)
422	Arnica latifolia	3 (6)	1 (3)	- (0)	4 (2)	- (0)	1 (1)	3 (1)	2 (1)	- (0)	1 (15)	1 (0)	- (0)
426	Aster conspicuus	- (0)	- (0)	3 (1)	1 (1)	6 (6)	1 (1)	5 (1)	- (0)	- (0)	- (0)	1 (1)	4 (1)
582	Aster engelmannii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
430	Astragalus miser	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
431	Balsamorhiza sagittata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
696	Caltha biflora	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
741	Castilleja covilleana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
438	Castilleja miniata	- (0)	1 (1)	- (0)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
595	Chaenactis douglasii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
442	Chimaphila umbellata	3 (1)	4 (1)	10 (1)	5 (1)	- (0)	4 (1)	8 (6)	- (0)	3 (1)	6 (4)	7 (2)	1 (1)
447	Clintonia uniflora	1 (3)	- (0)	10 (14)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
449	Coptis occidentalis	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
602	Crepis accuminata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
458	Dodecatheon jeffreyi	4 (2)	3 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (1)	- (0)
455	Disporum trachycarpum	- (0)	1 (1)	7 (1)	- (0)	4 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (1)	- (0)
459	Epilobium angustifolium	4 (1)	1 (1)	- (0)	- (0)	2 (1)	7 (1)	3 (1)	- (0)	2 (1)	1 (1)	3 (1)	3 (2)
465	Fragaria vesca	- (0)	- (0)	7 (2)	1 (1)	- (0)	- (0)	5 (2)	- (0)	- (0)	- (0)	4 (1)	1 (1)
466	Fragaria virginiana	4 (10)	7 (1)	7 (1)	1 (1)	- (0)	8 (4)	3 (3)	- (0)	2 (1)	- (0)	1 (1)	1 (1)
471	Galium triflorum	4 (1)	7 (1)	7 (2)	4 (1)	2 (3)	- (0)	8 (1)	- (0)	- (0)	1 (0)	5 (4)	1 (1)
620	Geranium richardsonii	- (0)	1 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
473	Geranium viscosissimum	2 (1)	1 (1)	- (0)	- (0)	4 (1)	2 (1)	5 (1)	- (0)	- (0)	- (0)	2 (1)	4 (1)
474	Geum triflorum	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
476	Goodyera oblongifolia	2 (1)	3 (1)	7 (2)	6 (1)	4 (1)	- (0)	3 (1)	- (0)	- (0)	4 (1)	7 (0)	3 (1)
484	Hieracium albiflorum	2 (2)	- (0)	3 (1)	1 (1)	- (0)	2 (1)	3 (1)	2 (1)	5 (1)	6 (2)	4 (1)	6 (1)
486	Hieracium gracile	1 (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	2 (0)	3 (1)	- (0)	- (0)	- (0)
636	Lathyrus nevadensis	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)
489	Ligusticum canbyi	5 (15)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (1)	- (0)	2 (1)	- (0)	- (0)
490	Ligusticum tenuifolium	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
497	Lomatium dissectum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
641	Lupinus argenteus	- (0)	- (0)	3 (1)	- (0)	- (0)	1 (15)	- (0)	2 (0)	- (0)	1 (1)	- (0)	- (0)
642	Lupinus polyphyllus	3 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)
649	Mitella pentandra	4 (1)	7 (12)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
502	Mitella stauropetala	- (0)	1 (1)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (1)	1 (0)
505	Osmorhiza chilensis	6 (8)	7 (1)	7 (2)	3 (1)	4 (1)	- (0)	3 (1)	- (0)	- (0)	4 (0)	7 (0)	7 (1)
653	Osmorhiza depauperata	1 (1)	3 (1)	- (0)	- (0)	- (0)	- (0)	5 (2)	- (0)	- (0)	- (0)	- (0)	1 (1)
507	Pedicularis bracteosa	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (0)	- (0)	- (0)
509	Pedicularis racemosa	6 (1)	1 (1)	7 (0)	3 (0)	- (0)	1 (1)	3 (15)	- (0)	5 (1)	9 (1)	3 (1)	- (0)
514	Penstemon wilcoxii	- (0)	- (0)	- (0)	- (0)	8 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
663	Phacelia hastata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
669	Potentilla diversifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
521	Potentilla flabellifolia	2 (2)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
670	Potentilla gracilis	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
526	Pyrola asarifolia	2 (2)	3 (2)	- (0)	3 (1)	- (0)	1 (1)	8 (1)	- (0)	- (0)	1 (1)	- (0)	- (0)
529	Pyrola secunda	7 (0)	10 (1)	10 (2)	10 (2)	2 (1)	1 (1)	- (2)	2 (1)	3 (1)	1 (1)	8 (3)	7 (1)
676	Saxifraga arguta	1 (0)	9 (10)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
538	Senecio pseudaureus	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
681	Senecio streptanthifolius	- (0)	- (0)	- (0)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)
539	Senecio triangularis	8 (9)	10 (16)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	2 (0)	- (0)
542	Smilacina racemosa	1 (1)	- (0)	10 (1)	3 (1)	10 (4)	- (0)	- (0)	- (0)	2 (1)	1 (1)	5 (1)	3 (0)
543	Smilacina stellata	3 (1)	1 (1)	7 (2)	1 (1)	- (0)	1 (1)	3 (15)	- (0)	- (0)	- (0)	1 (1)	- (0)
684	Solidago multiradiata	- (0)	1 (1)	- (0)	- (0)	- (0)	2 (2)	3 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
546	Streptopus amplexifolius	5 (0)	7 (11)	- (0)	4 (1)	- (0)	- (0)	3 (1)	- (0)	- (0)	- (0)	2 (2)	- (0)
547	Thalictrum occidentalis	10 (3)	6 (5)	10 (18)	4 (1)	8 (36)	1 (0)	8 (10)	- (0)	5 (0)	3 (5)	8 (7)	6 (1)
563	Trautvetteria caroliniensis	8 (42)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)
560	Trillium ovatum	6 (1)	- (0)	7 (2)	4 (1)	- (0)	1 (1)	5 (1)	- (0)	- (0)	4 (0)	3 (0)	- (0)
551	Valeriana sitchensis	5 (3)	3 (1)	7 (2)	4 (1)	8 (2)	2 (1)	3 (3)	2 (0)	7 (2)	4 (0)	8 (2)	3 (8)
552	Veratrum viride	5 (6)	- (0)	3 (1)	4 (1)	- (0)	- (0)	- (0)	4 (1)	- (0)	3 (1)	- (0)	- (0)
554	Viola adunca	2 (1)	1 (1)	7 (2)	- (0)	- (0)	5 (1)	- (0)	- (0)	- (0)	- (0)	2 (1)	3 (0)
693	Viola nuttallii	- (0)	- (0)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
557	Viola orbiculata	8 (3)	3 (2)	10 (1)	9 (4)	- (0)	2 (1)	5 (1)	2 (1)	5 (1)	6 (1)	3 (1)	- (0)
694	Viola purpurea	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
558	Xerophyllum tenax	5 (1)	- (0)	- (0)	3 (2)	- (0)	1 (37)	- (0)	10 (57)	10 (42)	10 (49)	- (0)	- (0)

APPENDIX C-1 (con)

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in central Idaho habitat types and phases.

ADP NUMBER	SPECIES	ABIES LASIOCARPA SERIES (con)												PICO
		LUHI h.t.		VASC h.t.			CARU h.t.	CAGE h.t.		JUCO h.t.	ARCO h.t.	RIMO h.t.	PIAL-ABLA h.t.s.	FEID h.t.
		VASC Phase	LUHI Phase	VASC Phase	CARU Phase	PIAL Phase		CAGE Phase	ARTR Phase					
		n= 5	n= 5	n=13	n= 3	n= 3	n=15	n=30	n= 3	n= 8	n=12	n= 5	n=15	n=12
	TREES													
001	Abies grandis	- (0)	- (0)	- (0)	- (0)	- (0)	1 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
002	Abies lasiocarpa	10 (48)	10 (55)	10 (40)	10 (7)	10 (34)	10 (27)	10 (37)	10 (38)	10 (19)	10 (35)	10 (38)	10 (19)	- (0)
006	Larix occidentalis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
007	Picea engelmannii	10 (4)	6 (2)	8 (8)	7 (1)	3 (3)	- (0)	3 (4)	- (0)	5 (20)	9 (12)	2 (15)	1 (0)	- (0)
009	Pinus albicaulis	6 (11)	8 (2)	6 (1)	- (0)	10 (46)	4 (0)	4 (6)	10 (15)	4 (6)	4 (2)	6 (26)	9 (18)	2 (3)
010	Pinus contorta	10 (20)	6 (0)	9 (17)	10 (53)	10 (11)	8 (18)	9 (23)	7 (2)	8 (30)	7 (9)	2 (0)	3 (10)	10 (43)
011	Pinus flexilis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (16)	- (0)	4 (1)	- (0)	2 (6)	- (0)	- (0)
013	Pinus ponderosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
014	Populus tremuloides	- (0)	- (0)	- (0)	- (0)	- (0)	3 (10)	+ (37)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
016	Pseudotsuga menziesii	- (0)	- (0)	1 (0)	7 (2)	- (0)	6 (33)	3 (14)	7 (8)	8 (22)	7 (37)	4 (0)	- (0)	- (0)
	SHRUBS and SUBSHRUBS													
102	Acer glabrum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
104	Alnus sinuata	- (0)	- (0)	2 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
105	Amelanchier alnifolia	- (0)	- (0)	1 (1)	- (0)	- (0)	1 (1)	1 (0)	3 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
201	Arctstaphylos uva-ursi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
150	Artemisia tridentata	- (0)	- (0)	- (0)	- (0)	- (0)	1 (19)	2 (0)	10 (23)	- (0)	- (0)	2 (1)	1 (8)	4 (17)
203	Berberis repens	- (0)	- (0)	- (0)	3 (1)	- (0)	3 (0)	1 (2)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)
107	Ceanothus velutinus	- (0)	- (0)	- (0)	- (0)	- (0)	1 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
173	Cercocarpus ledifolius	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
204	Clematis columbiana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)
205	Gaultheria humifusa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
111	Holodiscus discolor	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
112	Juniperus communis	- (0)	- (0)	1 (1)	- (0)	3 (3)	1 (1)	1 (2)	- (0)	10 (16)	4 (2)	- (0)	- (0)	1 (1)
113	Ledum glandulosum	- (0)	- (0)	1 (1)	3 (1)	3 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
206	Linnaea borealis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
154	Lonicera caerulea	- (0)	- (0)	- (0)	3 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
115	Lonicera utahensis	4 (1)	8 (0)	7 (1)	10 (1)	- (0)	1 (1)	2 (1)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)
116	Menziesia ferruginea	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
118	Pachistima myrsinites	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
122	Physocarpus malvaceus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
124	Prunus virginiana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
125	Purshia tridentata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	1 (0)
128	Ribes cereum	- (0)	- (0)	1 (15)	- (0)	- (0)	2 (3)	2 (1)	7 (2)	4 (2)	1 (1)	- (0)	- (0)	2 (0)
130	Ribes lacustre	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	3 (2)	1 (1)	- (0)	- (0)	- (0)
159	Ribes montigenum	- (0)	2 (3)	2 (0)	- (0)	- (0)	- (0)	4 (2)	3 (3)	3 (2)	4 (2)	10 (43)	1 (1)	- (0)
131	Ribes viscosissimum	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	2 (1)	- (0)	- (0)	- (0)
133	Rosa gymnocarpa	- (0)	- (0)	- (0)	3 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
161	Rosa nutkana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
134	Rosa woodsii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
136	Rubus parviflorus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)
137	Salix scouleriana	- (0)	- (0)	- (0)	3 (1)	- (0)	1 (0)	- (0)	- (0)	1 (3)	- (0)	- (0)	- (0)	- (0)
139	Sheperdia canadensis	- (0)	- (0)	- (0)	7 (0)	- (0)	- (0)	- (0)	- (0)	10 (18)	5 (1)	- (0)	- (0)	1 (1)
140	Sorbus scopulina	- (0)	- (0)	2 (1)	- (0)	- (0)	1 (15)	1 (2)	- (0)	- (0)	1 (1)	2 (3)	- (0)	- (0)
142	Spiraea betulifolia	- (0)	- (0)	2 (2)	3 (1)	- (0)	2 (1)	1 (1)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)
162	Spiraea pyramidata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
143	Symphoricarpos albus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
163	Symphoricarpos oreophilus	- (0)	- (0)	2 (2)	- (0)	- (0)	7 (4)	3 (2)	10 (6)	9 (3)	4 (2)	4 (1)	- (0)	- (0)
144	Taxus brevifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
145	Vaccinium caespitosum	2 (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
146	Vaccinium globulare	- (0)	- (0)	2 (2)	3 (1)	3 (3)	1 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
148	Vaccinium scoparium	10 (53)	4 (0)	10 (73)	10 (74)	10 (70)	1 (2)	1 (0)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)
	FERNS and FERN ALLIES													
253	Cystopteris fragilis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
254	Equisetum arvense	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
259	Pteridium aquilinum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
	GRAMINOIDS													
301	Agropyron spicatum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	3 (3)	- (0)	- (0)	- (0)	1 (3)	3 (1)
304	Bromus vulgaris	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	+ (1)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)
305	Calamagrostis canadensis	2 (3)	- (0)	- (0)	- (0)	- (0)	1 (37)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
307	Calamagrostis rubescens	- (0)	- (0)	2 (1)	10 (38)	- (0)	10 (45)	- (0)	3 (1)	3 (2)	1 (1)	- (0)	- (0)	2 (26)
308	Carex concinnoides	- (0)	- (0)	- (0)	3 (1)	- (0)	1 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)
339	Carex disperma	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
309	Carex geyeri	6 (1)	6 (2)	9 (13)	7 (8)	10 (3)	10 (13)	10 (32)	10 (23)	6 (1)	6 (1)	6 (2)	5 (2)	4 (4)
311	Carex rossii	8 (1)	8 (1)	5 (1)	7 (1)	3 (1)	6 (3)	3 (3)	3 (1)	5 (1)	3 (1)	4 (2)	5 (3)	8 (2)
316	Elymus glaucus	- (0)	2 (1)	2 (1)	- (0)	- (0)	1 (1)	+ (1)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)
317	Festuca idahoensis	- (0)	- (0)	1 (1)	- (0)	- (0)	2 (7)	4 (4)	- (0)	- (0)	1 (1)	4 (1)	4 (24)	10 (18)
348	Hesperochloa kingii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)
322	Juncus parryi	2 (3)	4 (0)	- (0)	- (0)	- (0)	- (0)	+ (15)	- (0)	- (0)	- (0)	- (0)	3 (43)	- (0)
323	Koeleria cristata	- (0)	- (0)	- (0)	- (0)	- (0)	1 (0)	+ (1)	- (0)	- (0)	- (0)	- (0)	1 (1)	3 (1)
325	Luzula hitchcockii	10 (17)	10 (77)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)
349	Melica bulbosa	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (1)	7 (2)	- (0)	- (0)	2 (1)	1 (31)	- (0)
331	Poa nervosa	2 (1)	- (0)	3 (0)	- (0)	3 (1)	4 (1)	6 (2)	7 (1)	6 (1)	2 (1)	4 (9)	3 (2)	6 (1)
360	Stipa occidentalis	- (0)	- (0)	- (0)	- (0)	- (0)	2 (1)	2 (1)	7 (3)	- (0)	- (0)	2 (1)	5 (15)	2 (3)

*Code to constancy values: + = 0-5 %, 1 = 5-15%, 2 = 15-25%, 3 = 25-35%, 4 = 35-45%, 5 = 45-55%, 6 = 55-65%, 7 = 65-75%, 8 = 75-85%, 9 = 85-95%, 10 = 95-100%

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in central Idaho habitat types and phases.

ADP NUMBER	SPECIES	ABIES LASIOCARPA SERIES (con)												PICO (con)
		LUHI h.t.		VASC h.t.			CARU h.t.	CAGE h.t.		JUCO h.t.	ARCO h.t.	RIMO h.t.	PIAL-ABLA h.t.s.	FEID h.t.
		VASC Phase	LUHI Phase	VASC Phase	CARU Phase	PIAL Phase		CAGE Phase	ARTR Phase					
		n= 5	n= 5	n=13	n= 3	n= 3	n=15	n=30	n= 3	n= 8	n=12	n= 5	n=15	n=12
	FORBS													
401	Achillaea millefolium	- (0)	2 (3)	1 (1)	3 (1)	10 (1)	8 (1)	6 (1)	7 (2)	3 (1)	2 (1)	6 (1)	4 (1)	4 (1)
402	Actaea rubra	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
565	Aconitum columbianum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
403	Adenocaulon bicolor	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
738	Antennaria corymbosa	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
414	Antennaria microphylla	- (0)	- (0)	1 (1)	- (0)	- (0)	3 (1)	4 (1)	3 (1)	4 (1)	1 (1)	- (0)	3 (1)	8 (4)
413	Antennaria racemosa	- (0)	- (0)	2 (1)	- (0)	- (0)	1 (1)	+ (1)	- (0)	5 (2)	6 (4)	- (0)	- (0)	- (0)
577	Arenaria aculeata	- (0)	- (0)	1 (1)	- (0)	3 (1)	3 (1)	2 (3)	- (0)	1 (1)	- (0)	2 (1)	7 (3)	1 (15)
420	Arenaria macrophylla	- (0)	2 (1)	2 (1)	- (0)	- (0)	2 (3)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
421	Arnica cordifolia	4 (1)	2 (1)	2 (2)	3 (1)	7 (20)	4 (10)	4 (7)	- (0)	10 (7)	10 (21)	8 (1)	- (0)	1 (1)
422	Arnica latifolia	6 (1)	6 (6)	5 (2)	- (0)	3 (1)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	3 (1)	- (0)
426	Aster conspicuus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	2 (2)	- (0)	- (0)	- (0)
582	Aster engelmannii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
430	Astragalus miser	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	4 (1)	- (0)	- (0)
431	Balsamorhiza sagittata	- (0)	- (0)	- (0)	- (0)	- (0)	1 (2)	+ (1)	3 (1)	- (0)	- (0)	- (0)	1 (3)	- (0)
696	Caltha biflora	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
741	Castilleja covilleana	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)
438	Castilleja miniata	- (0)	- (0)	1 (1)	- (0)	- (0)	1 (3)	1 (0)	- (0)	3 (8)	- (0)	- (0)	- (0)	- (0)
595	Chaenactis douglasii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
442	Chimaphila umbellata	2 (1)	- (0)	2 (2)	3 (1)	- (0)	2 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)
447	Clintonia uniflora	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
449	Coptis occidentalis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
602	Crepis accuminata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)
458	Dodecatheon jeffreyi	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
455	Disporum trachycarpum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
459	Epilobium angustifolium	4 (2)	2 (1)	4 (1)	3 (1)	7 (2)	3 (1)	4 (1)	3 (1)	9 (3)	3 (1)	4 (19)	1 (1)	1 (1)
465	Fragaria vesca	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
466	Fragaria virginiana	- (0)	- (0)	2 (1)	7 (1)	- (0)	2 (0)	2 (1)	- (0)	3 (1)	2 (1)	- (0)	- (0)	- (0)
471	Galium triflorum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
620	Geranium richardsonii	- (0)	- (0)	- (0)	- (0)	- (0)	1 (0)	+ (15)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
473	Geranium viscosissimum	- (0)	- (0)	1 (15)	- (0)	- (0)	1 (3)	+ (3)	- (0)	1 (1)	1 (1)	2 (1)	- (0)	- (0)
474	Geum triflorum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
476	Goodyera oblongifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)	3 (1)	- (0)	- (0)	- (0)	- (0)	- (0)
484	Hieracium albiflorum	- (0)	- (0)	2 (1)	- (0)	3 (1)	3 (1)	1 (0)	- (0)	- (0)	1 (1)	- (0)	1 (1)	- (0)
486	Hieracium gracile	4 (1)	2 (1)	2 (1)	3 (1)	- (0)	1 (1)	1 (1)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (1)
636	Lathyrus nevadensis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
489	Ligusticum canbyi	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
490	Ligusticum tenuifolium	2 (3)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
497	Lomatium dissectum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
641	Lupinus argenteus	- (0)	6 (2)	2 (2)	- (0)	3 (15)	1 (15)	2 (13)	- (0)	1 (15)	1 (3)	2 (15)	4 (14)	1 (15)
642	Lupinus polyphyllus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
649	Mitella pentandra	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
502	Mitella stauropetala	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
505	Osmorhica chilensis	- (0)	- (0)	1 (1)	- (0)	- (0)	1 (1)	1 (1)	- (0)	- (0)	1 (1)	2 (1)	1 (1)	- (0)
653	Osmorhica depauperata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	4 (1)	3 (1)	- (0)	1 (1)	- (0)
507	Pedicularis bracteosa	- (0)	2 (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
509	Pedicularis racemosa	6 (1)	2 (1)	3 (2)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)
514	Penstemon wilcoxii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
663	Phacelia hastata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	7 (1)	- (0)	- (0)	2 (1)	- (0)	- (0)
669	Potentilla diversifolia	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	1 (1)	- (0)	2 (1)	1 (1)	1 (1)
521	Potentilla flabellifolia	- (0)	2 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
670	Potentilla gracilis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	1 (1)	2 (1)	1 (1)	- (0)
526	Pyrola asarifolia	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
529	Pyrola secunda	- (0)	- (0)	2 (1)	3 (1)	3 (1)	1 (1)	2 (1)	- (0)	6 (1)	8 (5)	2 (0)	- (0)	- (0)
676	Saxifraga arguta	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
538	Senecio pseudaureus	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
681	Senecio streptanthifolius	- (0)	- (0)	1 (1)	- (0)	3 (1)	1 (1)	3 (1)	- (0)	8 (1)	4 (1)	2 (1)	1 (1)	1 (1)
539	Senecio triangularis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
542	Smilacina racemosa	- (0)	- (0)	1 (1)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)
543	Smilacina stellata	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
684	Solidago multiradiata	- (0)	- (0)	2 (1)	3 (1)	3 (3)	3 (4)	1 (5)	- (0)	9 (1)	3 (1)	2 (3)	- (0)	- (0)
546	Streptopus amplexifolius	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
547	Thalictrum occidentalis	- (0)	2 (1)	2 (2)	- (0)	- (0)	1 (9)	1 (1)	- (0)	3 (1)	3 (14)	- (0)	- (0)	- (0)
563	Trautvetteria caroliniensis	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
560	Trillium ovatum	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
551	Valeriana sitchensis	- (0)	6 (1)	6 (1)	3 (1)	10 (2)	3 (1)	3 (1)	- (0)	- (0)	2 (1)	- (0)	- (0)	- (0)
552	Veratrum viride	- (0)	4 (8)	- (0)	- (0)	- (0)	1 (1)	+ (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
554	Viola adunca	- (0)	- (0)	- (0)	- (0)	- (0)	3 (1)	1 (2)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
693	Viola nuttallii	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	+ (1)	- (0)	- (0)	- (0)	4 (1)	- (0)	1 (1)
557	Viola orbiculata	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (3)	- (0)
694	Viola purpurea	- (0)	- (0)	- (0)	- (0)	- (0)	1 (1)	1 (1)	7 (1)	- (0)	- (0)	2 (1)	3 (4)	3 (1)
558	Xerophyllum tenax	4 (1)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)

APPENDIX C-2

(See pocket inside back cover)

APPENDIX D-1. SUBSTRATE FEATURES OF CENTRAL IDAHO HABITAT TYPES AND PHASES

Substrate features of central Idaho habitat types and phases

Soil Characteristics	PIFL	PINUS PONDEROSA SERIES							PSEUDOTSUGA MENZIESII SERIES						
	FEID h.t.	STOC h.t.	AGSP h.t.	FEID h.t.	PUTR h.t.		SYOR h.t.	SYAL h.t.	AGSP h.t.	FEID h.t.		CELE h.t.	SYOR h.t.	ARCO h.t.	
					FEID phase	AGSP phase				PIPO phase	FEID phase			ASMI phase	ARCO phase
	n=3	n=3	n=18	n=7	n=3	n=11	n=3	n=11	n=20	n=6	n=11	n=6	n=26	n=6	n=22
COARSE FRAGMENT TYPES (percent of stands)															
SEDIMENTARY															
Calcarceous	67	--	--	--	--	--	--	--	--	--	10	17	10	33	37
Noncalcarceous	--	--	--	--	--	--	--	--	--	--	--	17	--	33	5
METAMORPHIC															
Quartzite	33	--	--	--	--	--	--	--	12	--	30	17	26	--	26
Gneiss & schist	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5
Miscellaneous	--	--	--	--	--	--	--	--	--	--	--	--	--	33	--
IGNEOUS															
Basalt & andesite	--	--	28	29	67	30	67	55	24	33	10	--	16	--	21
Dacite, trachyte & latite	--	--	--	--	--	--	--	9	12	17	30	--	26	--	5
Rhyolite	--	--	--	--	--	10	--	--	--	--	--	--	--	--	--
Other volcanics	--	--	--	--	--	--	--	--	--	17	--	33	--	--	--
Quartz monzonite & granitic	--	--	--	14	--	--	--	--	--	17	--	17	10	--	--
Granitics (undifferentiated)	--	67	72	57	33	60	33	36	53	17	20	--	5	--	--
Miscellaneous	--	33	--	--	--	--	--	--	--	--	--	--	5	--	--
MIXED	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
SUBSTRATE CHARACTERISTICS															
EXPOSED ROCK (mean %)	10	5	22	4	6	5	2	3	14	3	8	18	19	1	8
EXPOSED SOIL (mean %)	2	16	30	4	15	8	6	1	16	1	10	10	4	0.2	2
LITTER DEPTH (mean con)	1.6	3.2	1.5	3.0	2.8	2.4	2.6	4.9	1.8	3.1	1.8	0.7	3.0	2.6	3.6
REACTION (mean pH)	7.6	5.7	6.0	6.1	5.9	5.9	6.2	5.9	6.1	6.0	6.1	6.4	6.8	--	6.8
GRAVEL CONTENT (mean %)	20	17	8	12	7	12	12	5	20	19	39	30	41	39	41
TEXTURAL CLASS (percent of stands)															
Loamy sand	--	--	23	14	33	18	--	--	--	--	--	--	17	--	--
Sandy loam	--	67	47	29	33	36	--	27	41	16	14	33	22	--	21
Loam	67	33	12	43	33	36	33	36	47	67	57	67	48	--	68
Silt loam & silt	33	--	--	--	--	--	--	9	12	16	28	--	13	--	10
Silty clay loam & clay loam	--	--	18	14	--	9	67	27	--	--	--	--	--	--	--

(Con.)

Substrate features of central Idaho habitat types and phases (con.)

Soil Characteristics	PSEUDOTSUGA MENZIESII SERIES (con.)													
	JUCO h.t.	CAGE h.t.			BERE h.t.			CARU h.t.			OSCH h.t.	SPBE h.t.		
		SYOR phase	CAGE phase	PIPO phase	SYOR phase	BERE phase	CAGE phase	PIPO phase	CARU phase	FEID phase		CARU phase	SPBE phase	PIPO phase
	n=13	n=11	n=14	n=13	n=3	n=13	n=5	n=16	n=31	n=2	n=7	n=5	n=9	n=25
COARSE FRAGMENT TYPES (percent of stands)														
SEDIMENTARY														
Calcarceous	33	--	--	--	--	--	--	--	--	--	--	--	--	--
Noncalcarceous	--	--	--	--	--	--	--	--	--	--	--	--	--	--
METAMORPHIC														
Quartzite	50	11	17	--	--	--	--	--	38	--	--	75	14	--
Gneiss & schist	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Miscellaneous	--	--	--	--	--	--	--	--	--	--	--	--	--	--
IGNEOUS														
Basalt & andesite	--	22	25	25	--	27	--	21	12	--	43	--	14	38
Dacite, trachyte & latite	--	11	17	--	--	--	--	14	--	--	--	25	14	--
Rhyolite	--	11	--	--	--	--	--	--	--	--	14	--	--	--
Other volcanics	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Quartz monzonite & granitic	--	--	8	8	--	--	60	14	19	--	--	--	29	--
Granitics (undifferentiated)	17	44	33	67	100	64	20	50	31	--	43	--	14	62
Miscellaneous	--	--	--	--	--	9	--	--	--	--	--	--	14	--
MIXED	--	--	--	--	--	--	20	--	--	--	--	--	--	--
SUBSTRATE CHARACTERISTICS														
EXPOSED ROCK (mean %)	15	7	4	4	35	2	6	0.5	5	--	1	2	18	8
EXPOSED SOIL (mean %)	2	7	4	7	1	1	3	2	2	--	1	1	4	5
LITTER DEPTH (mean con)	3.5	1.4	2.6	3.5	1.6	4.1	3.3	3.8	3.3	--	4.7	2.3	2.2	3.7
REACTION (mean pH)	7.1	5.9	5.9	5.8	5.6	6.0	6.0	6.0	6.3	--	5.8	6.4	6.6	5.9
GRAVEL CONTENT (mean %)	31	43	42	8	24	16	37	15	31	--	18	24	34	9
TEXTURAL CLASS (percent of stands)														
Loamy sand	--	11	10	25	--	17	20	20	--	--	--	--	--	12
Sandy loam	--	44	30	25	67	33	40	27	35	--	40	40	38	28
Loam	40	44	50	42	33	50	40	53	65	--	60	60	62	56
Silt loam & silt	60	--	10	--	--	--	--	--	--	--	--	--	--	--
Silty clay loam & clay loam	--	--	--	8	--	--	--	--	--	--	--	--	--	4

(Con.)

APPENDIX D-1 (con.)

Substrate features of central Idaho habitat types and phases (con.)

Soil Characteristics	PSEUDOTSUGA MENZIESII SERIES (con.)						PIEN SERIES		ABIES GRANDIS SERIES						
	SYAL h.t.		ACGL h.t.		PHMA h.t.		CADI h.t.	HYRE h.t.	CARU h.t.	SPBE h.t.	VAGL h.t.	ACGL h.t.		LIBO h.t.	
	SYAL phase n=3	PIPO phase n=20	SYOR phase n=5	ACGL phase n=8	PSME phase n=13	PIPO phase n=27	n=7	n=5	n=7	n=8	n=12	PHMA phase n=12	ACGL phase n=14	VAGL phase n=4	LIBO phase n=4
COARSE FRAGMENT TYPES (percent of stands)															
SEDIMENTARY															
Calcarceous	--	--	50	--	--	--	--	100	--	--	--	--	--	--	--
Noncalcarceous	--	--	--	17	--	--	--	--	--	--	--	--	--	33	--
METAMORPHIC															
Quartzite	50	--	50	--	20	--	--	--	--	--	--	--	--	--	--
Gneiss & schist	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Miscellaneous	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
IGNEOUS															
Basalt & andesite	--	28	--	17	20	23	--	--	43	50	40	30	31	33	33
Dacite, trachyte & latite	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rhyolite	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Other volcanics	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Quartz monzonite & granitic	50	17	--	17	10	4	--	--	--	--	--	--	--	--	--
Granitics (undifferentiated)	--	44	--	33	30	64	--	--	14	38	50	40	62	33	33
Miscellaneous	--	--	--	17	--	--	--	--	--	--	--	10	7	--	--
MIXED	--	11	--	--	20	9	--	--	43	12	10	20	--	--	33
SUBSTRATE CHARACTERISTICS															
EXPOSED ROCK (mean %)	0.3	3	8	5	12	0.7	0	2	1	1	0	0.3	0	0	0.5
EXPOSED SOIL (mean %)	1	0.2	2	1	2	0.5	0	0.4	1	0.2	0	1	0.8	0.2	1
LITTER DEPTH (mean con)	3.2	4.8	4.1	4.7	4.9	4.8	14.0	2.8	2.7	3.9	3.9	3.6	4.4	3.6	4.6
REACTION (mean pH)	6.6	6.2	--	6.3	6.5	6.3	5.6	8.0	6.1	6.0	5.9	6.3	6.0	6.3	5.8
GRAVEL CONTENT (mean %)	41	17	--	19	24	15	3	27	3	4	2	4	10	21	5
TEXTURAL CLASS (percent of stands)															
Loamy sand	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sandy loam	--	37	--	25	11	40	--	--	50	25	20	38	57	--	--
Loam	100	47	33	75	67	55	--	--	25	62	80	50	43	--	--
Silt loam & silt	--	5	67	--	22	--	--	--	--	--	--	--	--	--	--
Silty clay loam & clay loam	--	10	--	--	--	5	--	--	25	12	--	12	--	--	--

(con.)

APPENDIX D-1 (con.)

Substrate features of central Idaho habitat types and phases (con.)

Soil Characteristics	ABGR S (con.)		ABIES LASIOCARPA SERIES											
	VACA h.t.	CLUN h.t.	CABI h.t.	CACA h.t.				STAM h.t.		CLUN h.t.	MEFE h.t.	ACGL h.t.	VACA h.t.	LIBO h.t.
				CACA phase	VACA phase	LICA phase	LEGL phase	LICA phase	STAM phase					
	n=8	n=15	n=8	n=7	n=8	n=14	n=11	n=11	n=7	n=3	n=8	n=5	n=13	n=4
COARSE FRAGMENT TYPES (percent of stands)														
SEDIMENTARY														
Calcarceous	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Noncalcarceous	--	--	--	--	--	--	--	--	--	--	--	--	--	--
METAMORPHIC														
Quartzite	--	--	--	67	17	9	--	--	17	--	--	--	--	--
Gneiss & schist	--	8	--	--	--	--	--	--	--	--	20	--	--	--
Miscellaneous	--	--	--	--	--	--	--	--	--	--	--	--	--	--
IGNEOUS														
Basalt & andesite	--	50	--	--	--	--	--	17	33	--	--	--	--	--
Dacite, trachyte & latite	--	--	--	--	--	--	12	--	--	--	--	--	9	--
Rhyolite	--	--	--	--	--	--	--	--	17	--	--	--	--	--
Other volcanics	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Quartz monzonite & granitic	--	--	20	33	--	--	12	--	17	--	--	20	--	--
Granitics (undifferentiated)	--	33	60	--	83	82	75	83	17	100	80	60	73	--
Miscellaneous	--	--	20	--	--	--	--	--	--	--	--	--	--	--
MIXED	--	8	--	--	--	9	--	--	--	--	--	20	18	--
SUBSTRATE CHARACTERISTICS														
EXPOSED ROCK (mean %)	0	0.2	0.6	0.1	0	1	1	0.5	0.4	0	0.7	0.4	0.3	5
EXPOSED SOIL (mean %)	0	0.3	0.3	0.1	0.3	0.5	0	0.1	0.7	0	2	1	1	0
LITTER DEPTH (mean con)	1.8	4.8	7.5	4.4	3.1	4.6	5.3	4.3	8.0	6.5	6.0	3.4	2.4	4.7
REACTION (mean pH)	5.3	5.9	5.2	5.3	5.0	5.1	5.1	5.1	5.6	5.5	5.4	5.8	5.2	5.5
GRAVEL CONTENT (mean %)	7	4	19	13	16	8	10	10	14	2	10	18	24	2
TEXTURAL CLASS (percent of stands)														
Loamy sand	--	--	--	--	--	--	17	--	--	--	--	--	8	--
Sandy loam	--	59	29	29	14	27	17	14	25	67	50	60	50	33
Loam	--	50	71	71	86	73	67	86	75	33	50	40	25	33
Silt loam & silt	--	--	--	--	--	--	--	--	--	--	--	--	8	--
Silty clay loam & clay loam	--	--	--	--	--	--	--	--	--	--	--	--	--	33

(Con.)

APPENDIX D-1 (con.)

Substrate features of central Idaho habitat types and phases (con.)

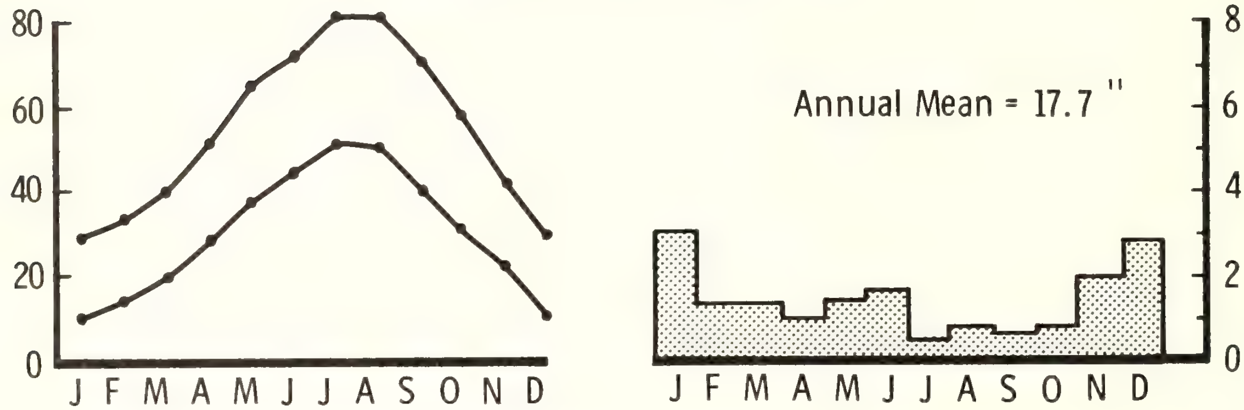
Soil Characteristics	ABIES LASIOCARPA SERIES (con.)																	PICO SERIES
	XETE h.t.			VAGL h.t.	SPBE h.t.	LUHI h.t.		VASC h.t.			CARU h.t.	CAGE h.t.		JUCO h.t.	ARCO h.t.	RIMO h.t.	PIAL/ ABLA h.t.s.	FEID h.t.
	LUHI phase n=5	VASC phase n=6	VAGL phase n=9	n=11	n=7	VASC phase n=5	LUHI phase n=5	VASC phase n=13	CARU phase n=3	PIAL phase n=3	n=15	CAGE phase n=30	ARTR phase n=3	n=8	n=12	n=5	n=15	n=12
	COARSE FRAGMENT TYPES (percent of stands)																	
SEDIMENTARY																		
Calcarceous	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	50	--	--
Noncalcarceous	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
METAMORPHIC																		
Quartzite	--	20	12	--	--	--	--	27	--	--	--	28	--	62	56	50	8	18
Gneiss & schist	40	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Miscellaneous	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
IGNEOUS																		
Basalt & andesite	--	20	--	--	--	25	--	9	33	--	21	5	--	--	--	--	--	18
Dacite, trachyte & latite	--	--	--	--	--	--	--	9	--	--	14	14	33	38	33	--	--	--
Rhyolite	--	--	--	11	--	--	--	--	--	--	--	5	--	--	--	--	--	--
Other volcanics	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Quartz monzonite & granitic	--	--	--	11	33	--	--	9	33	--	7	14	--	--	11	--	17	36
Granitics (undifferentiated)	60	60	88	56	67	75	100	36	33	--	57	28	67	--	--	--	67	27
Miscellaneous	--	--	--	--	--	--	--	9	--	--	--	--	--	--	--	--	--	--
MIXED	--	--	--	22	--	--	--	--	--	--	--	5	--	--	--	--	8	--
	SUBSTRATE CHARACTERISTICS																	
EXPOSED ROCK (mean)	0.6	2	8	0.6	5	2	11	2	0.8	4	1	3	4	13	3	5	15	3
EXPOSED SOIL (mean)	0.6	4	0.6	0.4	0.1	3	4	2	0	2	[illegible]	7	18	3	2	4	24	7
LITTER DEPTH (mean con)	2.6	2.2	3.6	3.8	3.3	2.3	1.9	2.3	1.6	0.9	1.9	2.2	2.5	1.7	2.7	2.3	--	0.7
REACTION (mean pH)	4.7	5.1	5.2	5.5	5.7	5.0	4.6	5.1	5.1	5.0	5.4	5.2	5.5	6.0	5.5	6.0	--	5.4
GRAVEL CONTENT (mean)	13	25	19	12	22	20	19	29	23	28	25	34	17	33	43	41	--	35
TEXTURAL CLASS (percent of stands)																		
Loamy sand	--	33	--	--	17	--	--	--	--	--	14	4	--	--	--	--	8	--
Sandy loam	67	--	25	44	33	25	25	27	33	--	28	26	67	12	44	--	67	36
Loam	33	67	75	55	50	75	75	73	67	--	57	70	33	88	56	--	25	64
Silt loam & silt	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Silty clay loam & clay loam	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

APPENDIX D-2. CLIMATIC PARAMETERS FOR WEATHER STATIONS WITHIN SELECTED HABITAT TYPES IN CENTRAL IDAHO

PINUS FLEXILIS SERIES

PIFL / ?

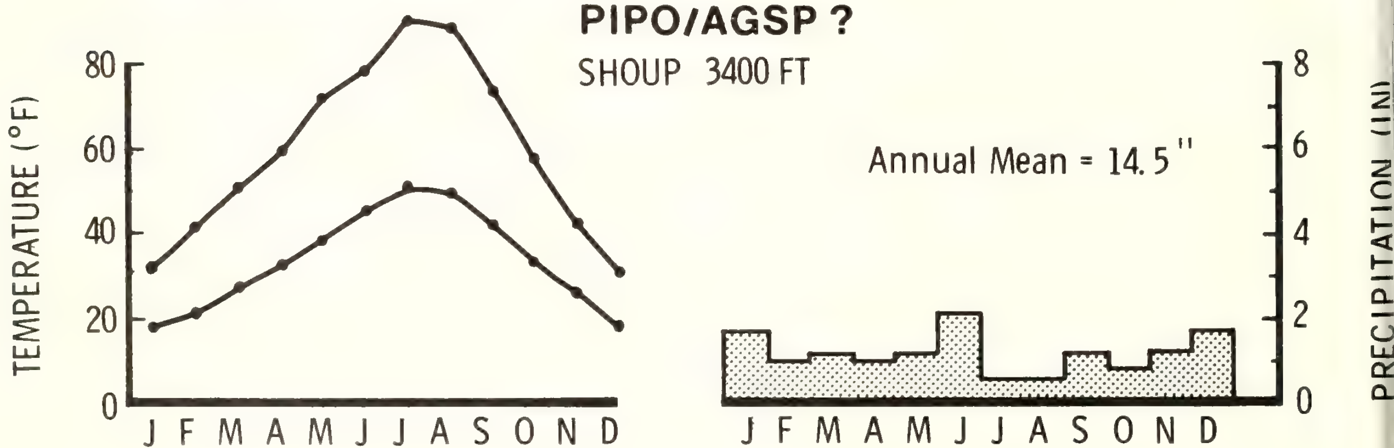
CRATERS OF THE MOON 5897 FT



PINUS PONDEROSA SERIES

PIPO/AGSP ?

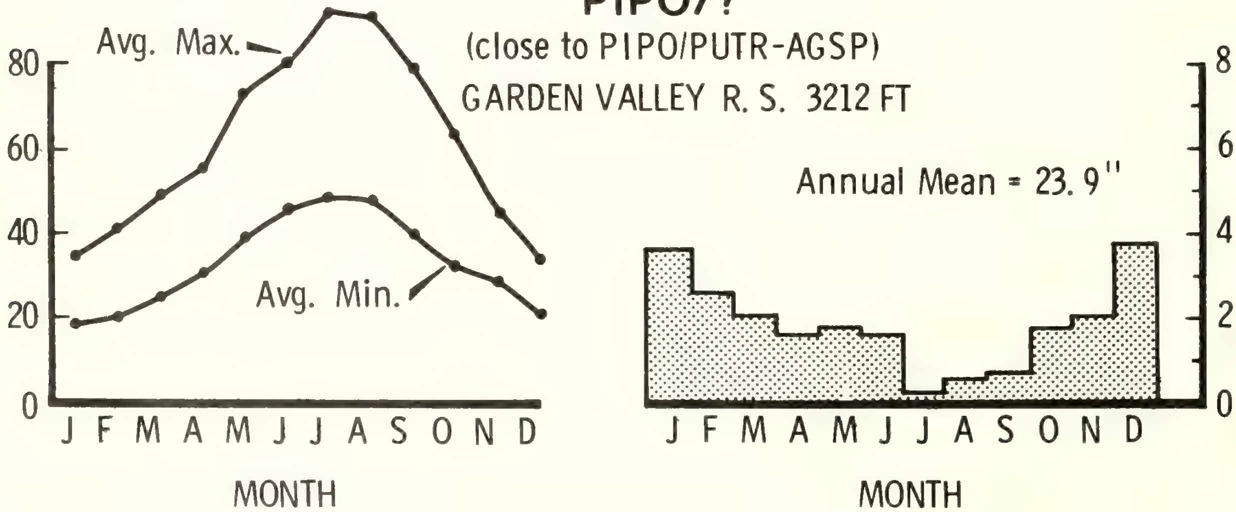
SHOUP 3400 FT



PIPO/?

(close to PIPO/PUTR-AGSP)

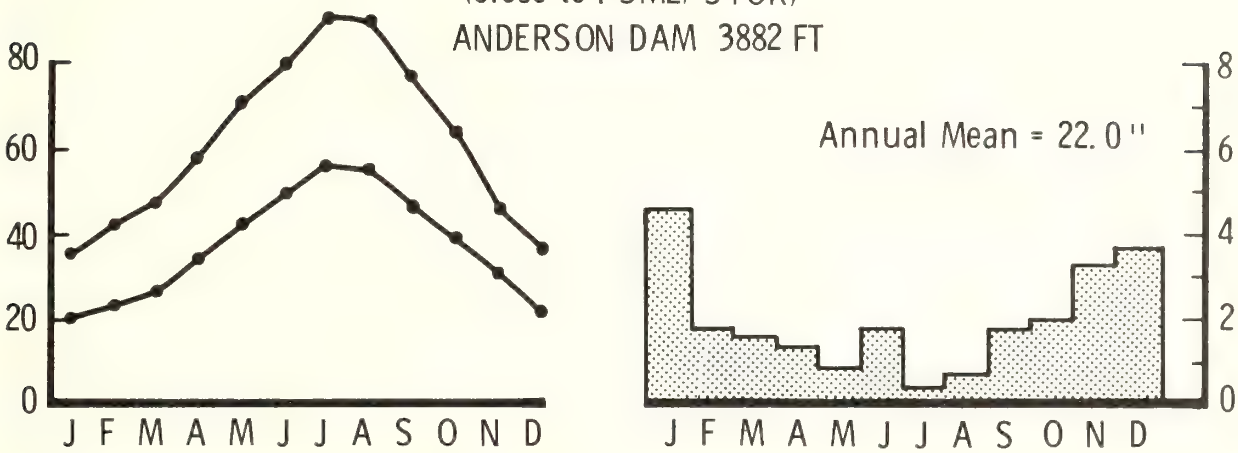
GARDEN VALLEY R. S. 3212 FT



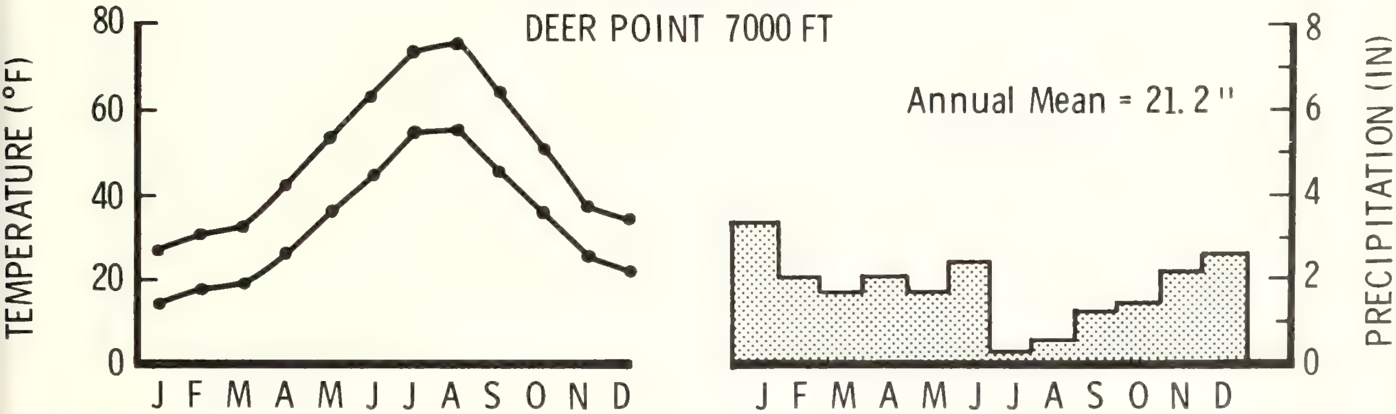
PSEUDOTSUGA MENZIESII SERIES

PSME–lower timberline

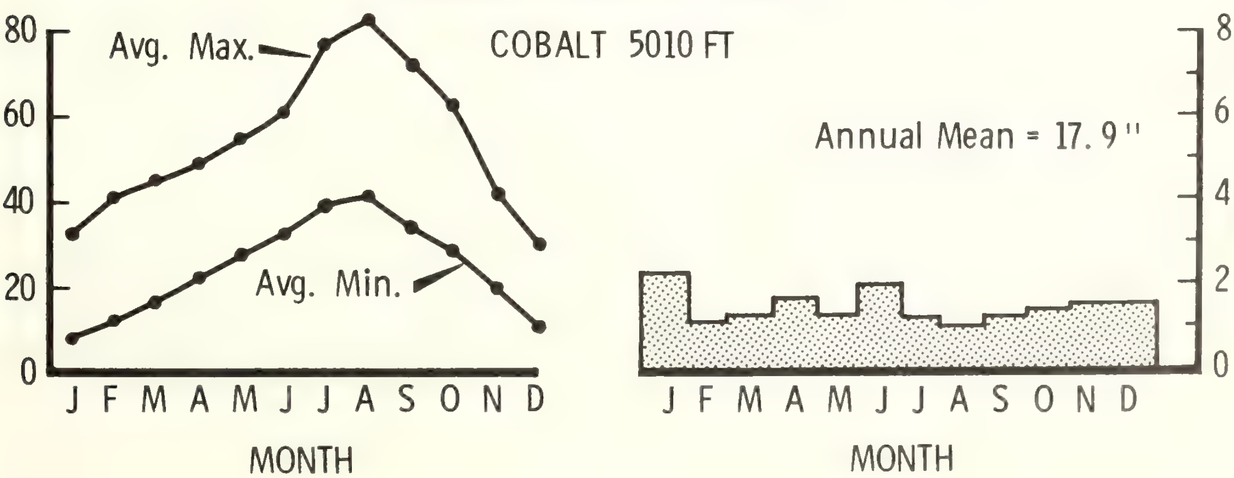
(close to PSME/ SYOR)



PSME/BERE–SYOR



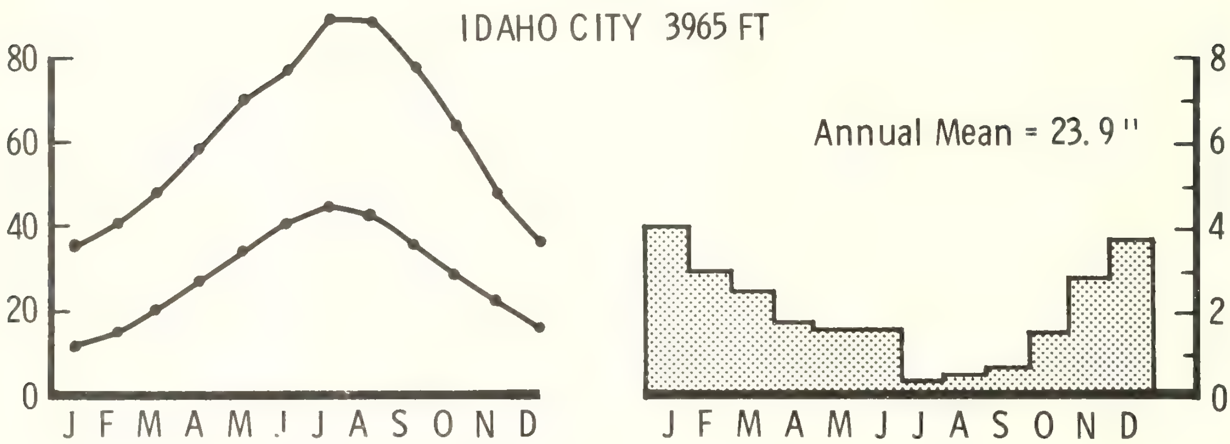
PSME/CARU–CARU



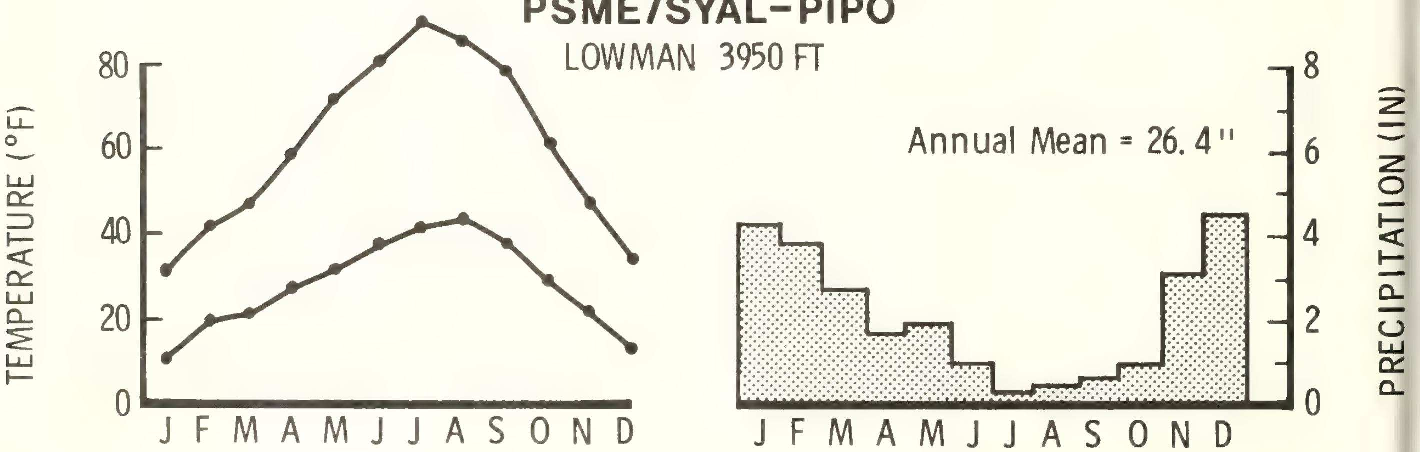
PSEUDOTSUGA MENZIESII SERIES

PSME/?

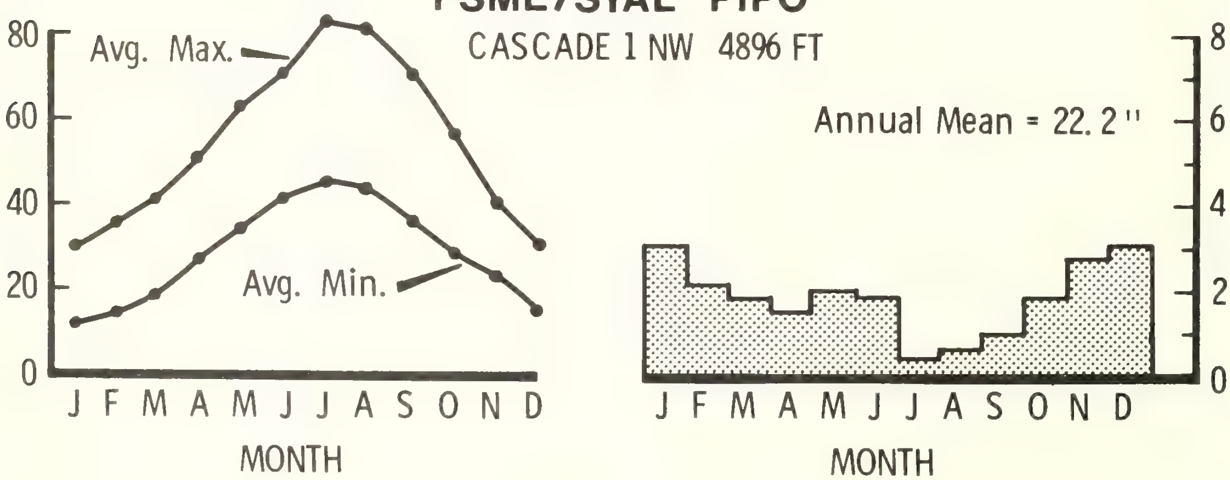
(close to PSME/SYAL-PIPO)



PSME/SYAL-PIPO



PSME/SYAL-PIPO

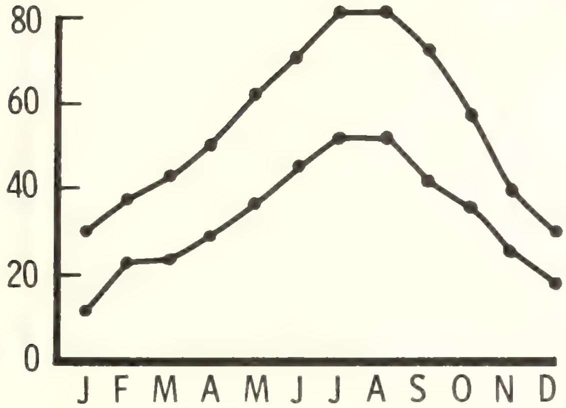


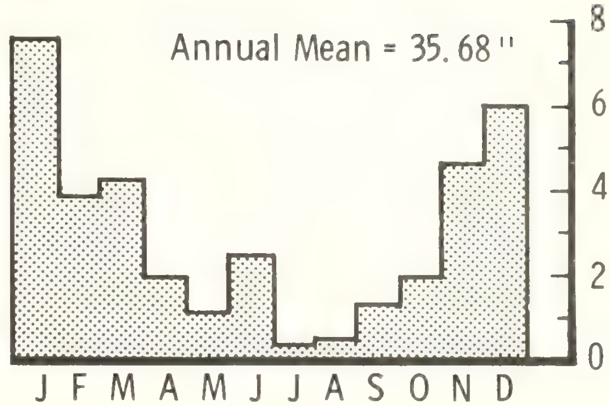
APPENDIX D-2. (con.)

PSEUDOTSUGA MENZIESII SERIES

PSME/PHMA-PIPO

PINE CREEK 4950 FT

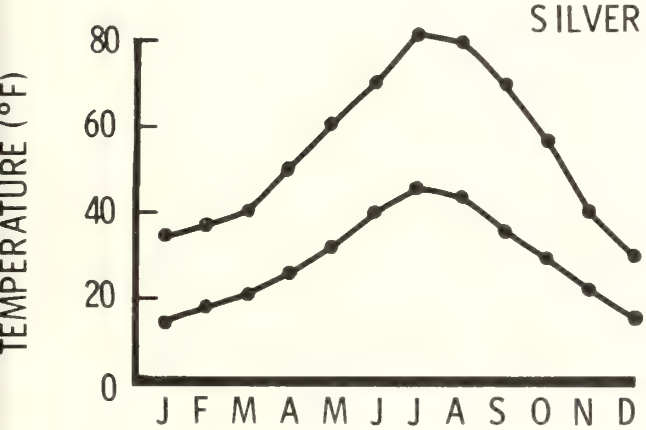


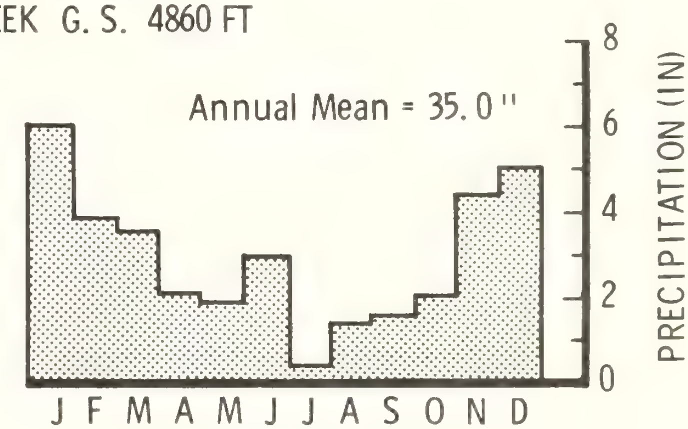


ABIES GRANDIS SERIES

ABGR/LIBO

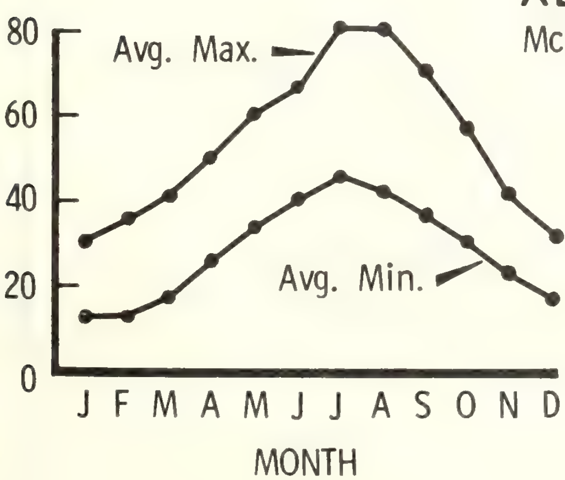
SILVER CREEK G. S. 4860 FT

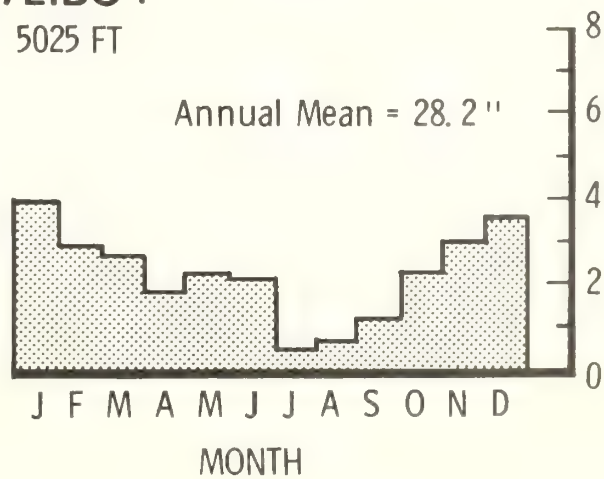




ABGR/LIBO?

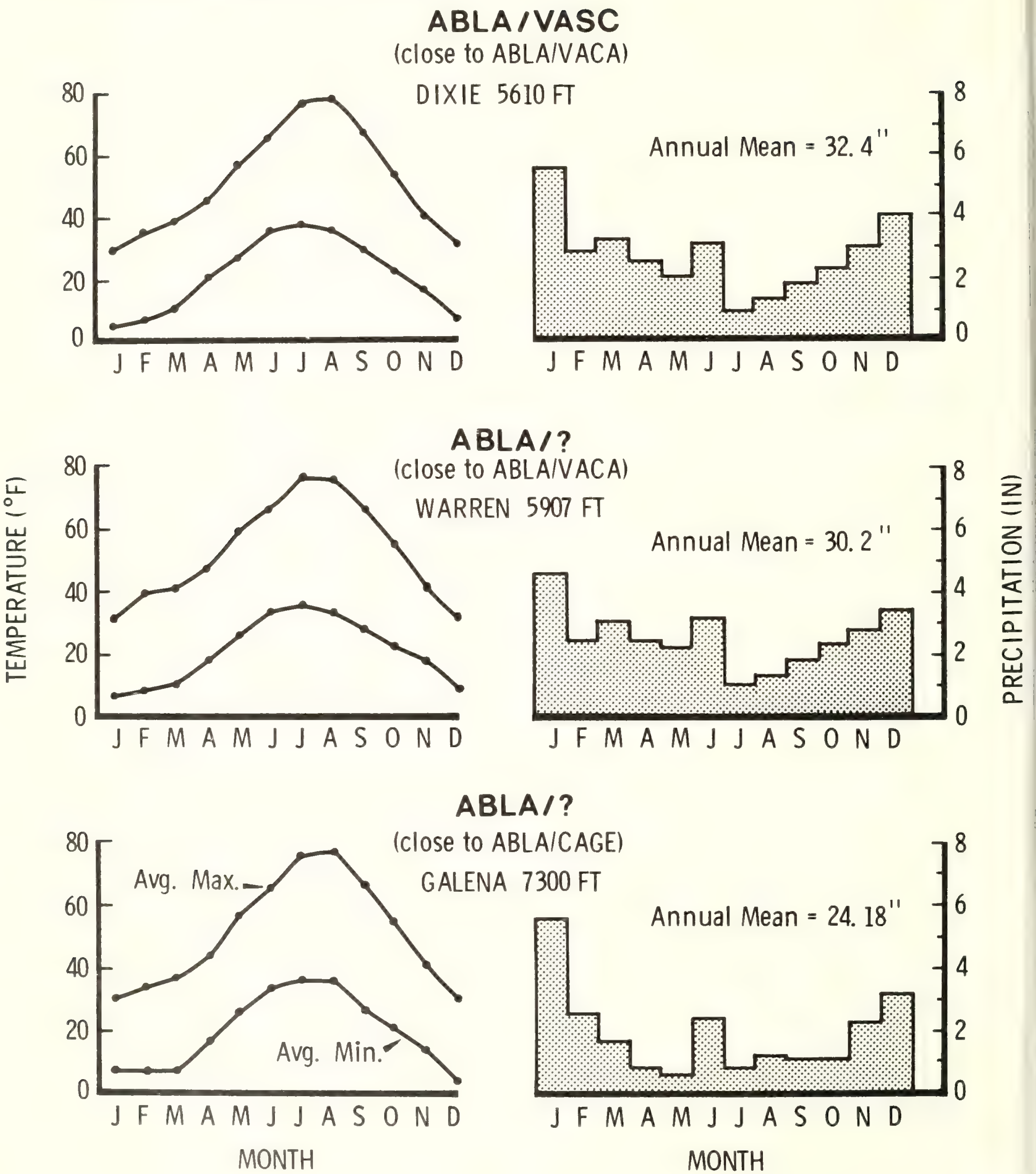
McCALL 5025 FT





APPENDIX D-2. (con.)

ABIES LASIOCARPA SERIES



APPENDIX E-1 · MEAN BASAL AREAS AND 50-YEAR SITE INDEXES FOR CENTRAL IDAHO STANDS BY HABITAT TYP
MEANS ARE SHOWN WHERE n = 3 OR MORE; CONFIDENCE LIMITS (95 PERCENT) FOR ESTIMATING THE MEAN A
GIVEN WHERE n = 5 OR MORE

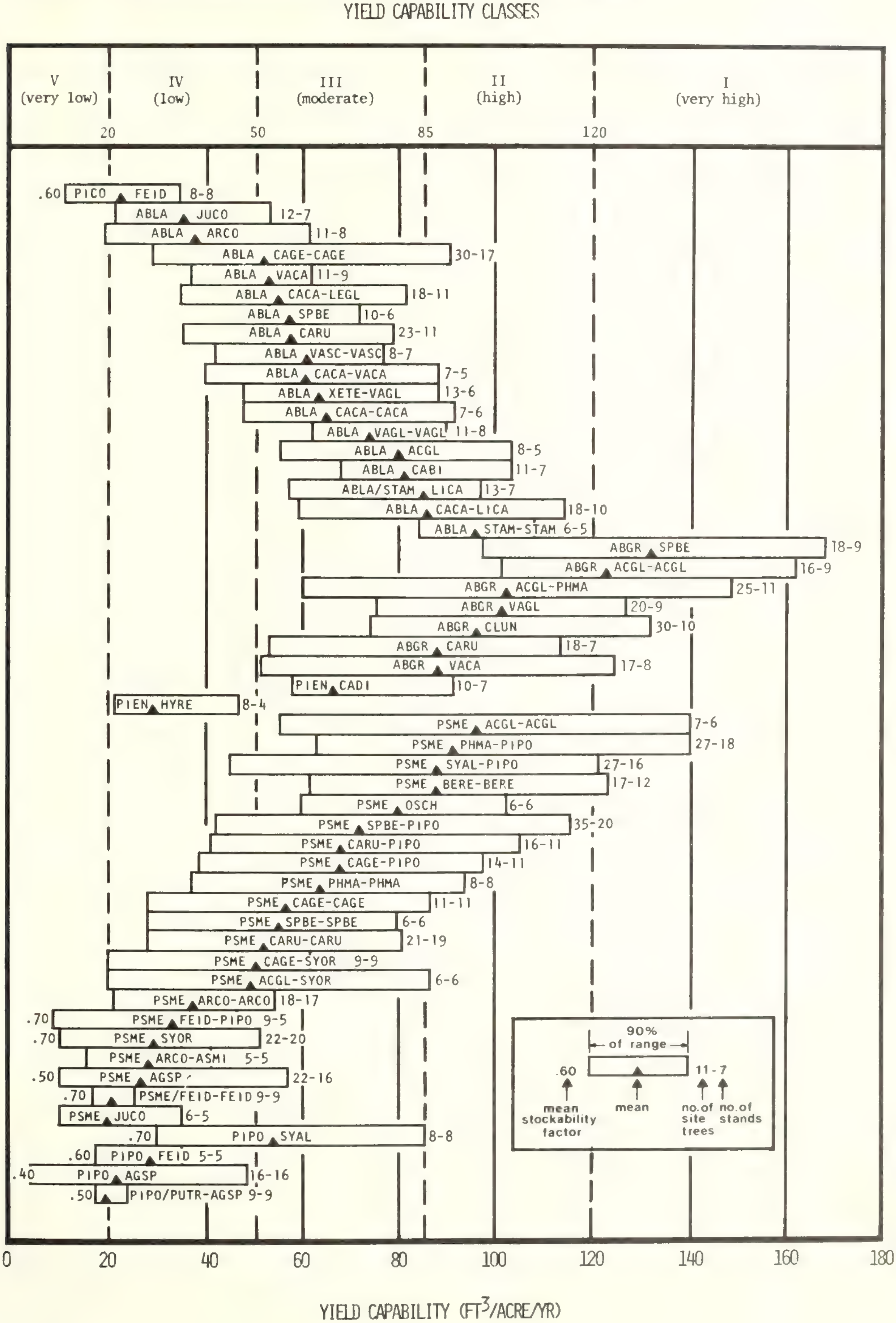
Habitat type	Basal area	Site index by species						
		PIPO	PSME	LAOC	PICO	ABGR	PIEN	ABLA
	Ft²/acre							
PIFL/FEID	114 ± ?	.	.	.	.	.	.	.
PIPO/STOC	82 ± ?	58 ± ?	.	.	.	.	.	.
PIPO/AGSP	84 ± 36	46 ± 7	.	.	.	.	.	.
PIPO/FEID	108 ± 62	46 ± 13	.	.	.	.	.	.
PIPO/PUTR, AGSP	101 ± 20	41 ± 8	.	.	.	.	.	.
PIPO/PUTR, FEID	.	.	.	.	.	.	.	.
PIPO/SYOR	.	.	.	.	.	.	.	.
PIPO/SYAL	179 ± 43	59 ± 7	.	.	.	.	.	.
PSME/AGSP	120 ± 34	49 ± 11	46 ± 5	.	.	.	.	.
PSME/FEID, FEID	122 ± 44	.	33 ± 4	.	.	.	.	.
PSME/FEID, PIPO	107 ± 74	47 ± 10	41 ± ?	.	.	.	.	.
PSME/SYOR	132 ± 35	.	39 ± 5	.	.	.	.	.
PSME/ARCO, ASMI	145 ± 34	.	29 ± 13	.	.	.	.	.
PSME/ARCO, ARCO	190 ± 34	.	36 ± 5	.	.	.	.	.
PSME/JUCO	183 ± 50	.	23 ± 15	.	.	.	.	.
PSME/CAGE, SYOR	128 ± 56	.	44 ± 14	.	.	.	.	.
PSME/CAGE, PIPO	156 ± 45	55 ± 11	52 ± ?	.	.	.	.	.
PSME/CAGE, CAGE	170 ± 66	.	49 ± 10	.	.	.	.	.
PSME/BERE, SYOR	223 ± ?	.	.	.	.	.	.	.
PSME/BERE, CAGE	242 ± ?	.	53 ± ?	.	.	.	.	.
PSME/BERE, BERE	226 ± 58	67 ± ?	63 ± 8	.	.	.	.	.
PSME/CELE	77 ± 58	.	28 ± ?	.	.	.	.	.
PSME/CARU, FEID	.	.	.	.	.	. .	.	.
PSME/CARU, PIPO	147 ± 45	60 ± 10	53 ± 16	.	44 ± ?	.	.	.
PSME/CARU, CARU	158 ± 41	.	45 ± 6	.	51 ± ?	.	.	.
PSME/OSCH	263 ± 107	.	57 ± 5	.	.	.	.	.
PSME/SPBE, PIPO	159 ± 32	59 ± 10	54 ± 6	.	.	.	.	.
PSME/SPBE, CARU	136 ± 44	.	46 ± ?	.	.	.	.	.
PSME/SPBE, SPBE	148 ± 44	.	48 ± 15	.	.	.	.	.
PSME/SYAL, PIPO	183 ± 33	66 ± 8	61 ± 10	.	.	.	.	.
PSME/SYAL, SYAL	.	.	.	.	.	.	.	.
PSME/ACGL, SYOR	150 ± 91	.	42 ± 20	.	.	.	.	.
PSME/ACGL, ACGL	212 ± 95	.	71 ± 29	.	.	.	.	.
PSME/PHMA, PIPO	195 ± 38	67 ± 10	62 ± 8	.	.	.	.	.
PSME/PHMA, PHMA	191 ± 54	.	52 ± 10	.	.	.	.	.
PIEN/HYRE	222 ± ?	.	31 ± ?	.	.	.	30 ± ?	.
PIEN/CADI	227 ± 52	.	.	.	.	.	54 ± 6	.
ABGR/CARU	174 ± 79	62 ± ?	61 ± 12	.	.	54 ± 25	.	.
ABGR/SPBE	261 ± 81	81 ± 11	73 ± 18	.	.	84 ± 17	.	.
ABGR/VAGL	224 ± 58	.	65 ± ?	.	53 ± ?	58 ± 13	77 ± ?	.
ABGR/ACGL, PHMA	207 ± 45	.	63 ± 15	.	.	61 ± 15	.	.
ABGR/ACGL, ACGL	232 ± 60	.	72 ± ?	.	.	71 ± 20	.	.
ABGR/LIBO, VAGL	202 ± ?	.	.	.	.	.	.	.
ABGR/LIBO, LIBO	206 ± ?	.	.	.	.	.	.	.
ABGR/VACA	131 ± 61	.	.	.	55 ± 7	74 ± ?	.	.
ABGR/CLUN	245 ± 54	.	66 ± 16	64 ± 6	.	50 ± 8	70 ± 16	.

con.

APPENDIX E-1 Continued.

Habitat type	Basal area	Site index by species						
		PIPO	PSME	LAOC	PICO	ABGR	PIEN	ABLA
	Ft²/acre							
ABLA/CABI	240 ± 127	.	.	.	.	.	58 ± 7	58 ± ?
ABLA/CACA, LEGL	158 ± 36	.	.	.	41 ± ?	.	45 ± 9	48 ± ?
ABLA/CACA, VACA	132 ± 14	.	.	.	51 ± 15	.	.	.
ABLA/CACA, LICA	209 ± 53	.	.	.	.	.	67 ± 10	57 ± 12
ABLA/CACA, CACA	161 ± 60	.	.	.	52 ± ?	.	52 ± ?	.
ABLA/STAM, LICA	204 ± 55	.	.	.	57 ± ?	.	62 ± 17	62 ± ?
ABLA/STAM, STAM	258 ± 86	.	.	.	.	.	65 ± ?	.
ABLA/CLUN, CLUN	.	.	.	.	.	.	.	.
ABLA/MEFE, MEFE	183 ± 53	.	.	.	.	.	65 ± ?	.
ABLA/ACGL	196 ± ?	.	54 ± ?	.	.	.	.	64 ± ?
ABLA/VACA	129 ± 34	.	.	.	48 ± 7	.	.	.
ABLA/LIBO, LIBO	212 ± ?	.	.	.	.	.	56 ± ?	.
ABLA/XETE, VAGL	194 ± 122	.	.	.	54 ± ?	.	51 ± ?	48 ± 6
ABLA/XETE, VASC	140 ± ?	.	.	.	.	.	.	.
ABLA/XETE, LUHI	136 ± ?	.	.	.	.	.	.	32 ± ?
ABLA/VAGL, VAGL	139 ± 51	.	54 ± 11	.	.	.	.	56 ± ?
ABLA/SPBE	150 ± 52	.	51 ± ?	.	45 ± ?	.	.	46 ± ?
ABLA/LUHI, VASC	.	.	.	.	.	.	.	.
ABLA/LUHI, LUHI	167 ± ?	.	.	.	.	.	.	.
ABLA/VASC, CARU	.	.	.	.	.	.	.	.
ABLA/VASC, VASC	130 ± 26	.	.	.	42 ± ?	.	.	51 ± ?
ABLA/VASC, PIAL	.	.	.	.	.	.	.	.
ABLA/CARU	154 ± 55	.	46 ± 16	.	43 ± 9	.	.	50 ± 7
ABLA/CAGE, CAGE	133 ± 21	.	49 ± ?	.	38 ± 7	.	.	42 ± 8
ABLA/CAGE, ARTR	207 ± ?	.	.	.	.	.	.	.
ABLA/JUCO	114 ± 20	.	38 ± ?	.	26 ± ?	.	29 ± ?	38 ± ?
ABLA/RIMO	96 ± 62	.	.	.	.	.	.	31 ± ?
ABLA/ARCO	171 ± 43	.	.	.	.	.	30 ± 12	35 ± 7
PIAL/ABLA	82 ± 55	.	.	.	.	.	.	.
PICO/FEID	94 ± 32	.	.	.	37 ± 5	.	.	.

APPENDIX E-2. ESTIMATED YIELD CAPABILITIES OF CENTRAL IDAHO HABITAT TYPES BASED ON SITE INDEX AND STOCKABILITY FACTORS



APPENDIX F. CENTRAL IDAHO HABITAT TYPE FIELD FORM

Central Idaho habitat type field form

Name

(Code Description)

Topography:	Horizontal Configuration:	Vegetation Coverage Class:	
1-Ridge			
2-Upper Slope	1-Convex (Dry)	0-None	3-25 to 50%
3-Mid Slope	2-Straight	T-Rare to 1%	4-50 to 75%
4-Lower Slope	3-Concave (wet)	1-1 to 5%	5-75 to 95%
5-Bench or Flat	4-Undulating	2-5 to 25%	6-95 to 100%
6-Streambottom			

Note: Rate trees (>4") and regen (0-4") separately (e.g. 4/2)

Date			
Plot No.			
Location			
T. R.			
Section			
Elevation			
Aspect			
Slope (%)			
Topography			
Configuration			

TREES	Abbrev.	Common Name	Canopy	Coverage	Class
1. Abies grandis	ABGR	grand fir	/	/	/
2. Abies lasiocarpa	ABLA	subalpine fir	/	/	/
3. Larix occidentalis	LAOC	western larch	/	/	/
4. Picea engelmannii	PIEN	Engelmann spruce	/	/	/
5. Pinus albicaulis	PIAL	whitebark pine	/	/	/
6. Pinus contorta	PICO	lodgepole pine	/	/	/
7. Pinus flexilis	PIFL	limber pine	/	/	/
8. Pinus ponderosa	PIPO	ponderosa pine	/	/	/
9. Pseudotsuga menziesii	PSME	Douglas-fir	/	/	/
10. Populus tremuloides	POTR	quaking aspen	/	/	/
SHRUBS AND VINES					
1. Acer glabrum	ACGL	mountain maple			
2. Alnus sinuata	ALSI	mountain alder			
3. Artemisia tridentata	ARTR	big sagebrush			
4. Berberis repens (+ aquifolium)	BERE	Oregon grape			
5. Cercocarpus ledifolius	CELE	curl-leaf mountain-mahogany			
6. Clematis columbiana	CLCO	rock clematis			
7. Holodiscus discolor	HODI	ocean-spray			
8. Juniperus communis	JUCO	common juniper			
9. Ledum glandulosum	LEGL	Labrador tea			
10. Linnaea borealis	LIBO	twinflower			
11. Menziesia ferruginea	MEFE	menziesia			
12. Physocarpus malvaceus	PHMA	ninebark			
13. Prunus virginiana	PRVI	chokecherry			
14. Purshia tridentata	PUTR	bitterbrush			
15. Ribes cereum	RICE	squaw current			
16 Ribes montigenum	RIMO	mountain gooseberry			
17. Spiraea betulifolia (+ pyramidata)	SPBE	white spirea			
18. Symphoricarpos albus	SYAL	common snowberry			
19. Symphoricarpos oreophilus	SYOR	mountain snowberry			
20. Vaccinium caespitosum	VACA	dwarf huckleberry			
21. Vaccinium globulare (+ membranaceum)	VAGL	blue huckleberry			
22. Vaccinium scoparium (+ myrtillus)	VASC	grouse whortleberry			
GRAMINOIDS					
1. Agropyron spicatum	AGSP	bluebunch wheatgrass			
2. Calamagrostis rubescens	CARU	pinegrass			
3. Calamagrostis canadensis	CACA	bluejoint			
4. Carex disperma	CADI	soft-leaved sedge			
5. Carex geyeri	CAGE	elks edge			
6. Festuca idahoensis	FEID	Idaho fescue			
7. Hesperochloa kingii	HEKI	spikefescue			
8. Luzula hitchcockii	LUHI	smooth woodrush			
9. Stipa occidentalis	STOC	western needlegrass			
FORBS, FERNS, AND FERN ALLIES					
1. Actaea rubra	ACRU	baneberry			
2. Adenocaulon bicolor	ADBI	trail-plant			
3. Arnica cordifolia	ARCO	heartleaf arnica			
4. Astragalus miser	ASMI	weedy milkvetch			
5. Caltha biflora	CABI	twinflower marsh marigold			
6. Clintonia uniflora	CLUN	queencup beadlily			
7. Coptis occidentalis	COOC	western goldthread			
8. Disporum trachycarpum	DITR	sierra fairybell			
9. Equisetum arvense	EQAR	common horsetail			
10. Lathyrus nevadensis cusickii	LANC	Cusick's peavine			
11. Ligusticum canbyi	LICA	Canby's ligusticum			
12. Osmorhiza chilensis	OSCH	mountain sweet-root			
13. Penstemon wilcoxii	PEWI	Wilcox's penstemon			
14. Senecio triangularis	SETR	arrowleaf groundsel			
15. Streptopus amplexifolius	STAM	twisted stalk			
16. Trautvetteria caroliniensis	TRCA	false bugbane			
17. Xerophyllum tenax	XETE	beargrass			

Series			
Habitat type			
Phase			

APPENDIX G. GLOSSARY

Glossary

Certain terms used in this report have various definitions among technical specialists; therefore, we compiled a glossary to minimize misunderstanding. Hanson (1962) and Ford-Robertson (1971) were the primary references.

Abundant. When relating to plant coverage in the habitat type key, any species having a canopy coverage of 25 percent or more in a stand.

Accidental. A species that is found rarely or at most occasionally as scattered individuals in a given habitat type.

Association. Climax plant (forest) community type.

Basal area. The area of the cross-section of a tree trunk 4.5 feet above the ground, usually expressed as the sum of tree basal areas in square feet per acre.

Bench, benchland. An area having flat or gently-sloping terrain (less than 15 percent slope), applied usually to the higher ground in a river valley.

Browse. Shrubby forage utilized especially by big game. (verb) To eat shrubby forage.

Canopy coverage. The area covered by the gross outline of an individual plant's foliage, or collectively covered by all individuals of a species within a stand or sample plot. Canopy coverage is expressed as a percentage of the total area in the plot, or as a canopy coverage class (for example, class #1 = 1 to 5 percent coverage).

Climax community. The culminating stage in plant (forest) succession for a given environment, that develops and perpetuates itself in the absence of disturbance.

Climax species. A species that is self-regenerating in the absence of disturbance, with no evidence of replacement by other species.

Climax, types of . . . in relation to environment (Polyclimax Concept).

- **Climatic climax.** The climax that develops on "normal" (well-drained, medium-textured) soils and gently sloping topography.
- **Edaphic climax.** A variation from the climatic climax caused by "abnormal" soil conditions.
- **Topographic climax.** A variation from the climatic climax caused by topography that markedly influences microclimate.
- **Topo-edaphic climax.** A variation from the climatic climax caused by the combination of topographic and edaphic effects. (Example: *Pseudotsuga menziesii* stands occupying rocky north-slopes surrounded by nonforest habitat types.)

Common. When relating to plant coverage in the habitat type key, any species having a canopy coverage of 1 percent or more in a stand.

Community (plant community). An assembly of plants living together, reflecting no particular ecological status.

Constancy. The percentage of stands in a habitat type that contain a given species. (Appendix C-1 uses "constancy classes" — "1" = 5 to 15 percent, "2" = 15 to 25 percent, etc.)

d.b.h. (diameter at breast height). Tree-trunk diameter measured 4.5 feet above the ground.

Depauperate. Describing an unusually sparse coverage of undergrowth vegetation. This condition usually develops beneath an especially dense forest canopy, often on sites having a deep layer of duff.

Disjunct. A small segment of a population that is separated geographically from the main population.

Ecosystem. Any community of organisms along with its environment that forms an interacting system.

Ecotone. The boundary or transition zone between adjacent plant communities, often delineating different habitat types.

Ecotype. A genetic race of a species that is adapted to a particular habitat.

Edaphic. Refers to soil.

Endemic. Confined naturally to particular geographic area.

Forb. An herbaceous plant that is not a graminoid.

Frequency. The percentage of quadrats (tiny plots) in a single sample stand that contain a given species, or more generally the degree of uniformity with which individuals of a species are distributed in a stand.

Graminoid. All grasses (Gramineae) and grasslike plants, including sedges *(Carex)* and rushes *(Juncus).*

Habitat type. An aggregation of all land areas potentially capable of producing similar plant communities at climax.

Indicator plant. A plant whose presence or abundance indicates the presence of certain environmental conditions — presence of a habitat type or phase.

Phase. A subdivision of an association and a habitat type representing minor differences in climax vegetation and environmental conditions, respectively.

Phenotype. A group of individuals distinguished on the basis of visible characteristics — in contrast to a "genotype" which is defined on the basis of genetic similarities.

Physiography. The study of the genesis and evolution of land forms.

Poorly represented. When relating to plant coverage in the habitat type key, any species that is absent or has a canopy coverage of less than 5 percent.

Riparian. Vegetation bordering watercourses, lakes, or swamps.

Scarce. When relating to plant coverage in the habitat type key, any species that is absent or has a canopy coverage of less than 1 percent.

Scree. Any slope covered with loose rock fragments. This includes accumulation of rock at the base of a cliff (talus) as well as loose material lying on slopes without cliffs.

Seral. A species or community that is replaced by another species or community as succession progresses.

Series. A group of habitat types having the same climax tree species. For example the *Pinus flexilis* series contains the *PIFL/HEKI, PIFL/FEID, PIFL/CELE,* and *PIFL/JUCO* h.t.s.

Site index. An index of timberland productivity based upon the height of specific trees at a certain reference age (usually 50 or 100 years).

Stand. A plant community that is relatively uniform in composition, structure, and habitat conditions; thus it may serve as a local example of a community type on a habitat type.

Stockability factor. An estimate of the stocking potential on a given site; for example a factor of 0.8 indicates that the site is capable of supporting only about 80 percent of "normal" stocking as indicated in yield tables.

Stocking. A general term for the number of trees (considering their size class) per acre.

Succession. The progressive changes in plant communities toward climax.

Union. A classified vegetation layer consisting of one or more species having similar environmental amplitudes within a geographic area; thus their presence is indicative of certain microenvironmental conditions.

Well represented. When relating to plant coverage in the habitat type key, any species having a canopy coverage of greater than 5 percent.

Yield capability. The maximum mean annual increment attainable in a fully stocked natural stand, expressed in cubic feet per acre per year. (See a forest mensuration textbook for the distinction between "mean annual increment" and "periodic annual increment"; growth in a specific year, or period of years, is termed the latter.)

Zone. An area of land named by a climatic climax vegetation type.

Steele, Robert, Robert D. Pfister, Russell A. Ryker, and Jay A. Kittams. 1981. Forest habitat types of central Idaho. USDA For. Serv. Gen. Tech. Rep. INT-114, 138 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

A land-classification system based upon potential natural vegetation is presented for the forests of central Idaho. It is based on reconnaissance sampling of about 800 stands. A hierarchical taxonomic classification of forest sites was developed using the habitat type concept. A total of eight climax series, 64 habitat types, and 55 additional phases of habitat types are defined and described. A diagnostic key is provided for field identification of the types based on indicator species used in development of the classification.

KEYWORDS: forest vegetation, Idaho, habitat types, plant communities, forest ecology, forest management, classification

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Figure 3.-- Key to climax series, habitat types, and phases.

READ THESE INSTRUCTIONS FIRST!

1. Use this key for stands with a mature tree canopy that are not severely disturbed by grazing, logging, forest fire, etc. (If the stand is severely disturbed or in an early successional stage, the habitat type can best be determined by extrapolation from the nearest mature stand occupying a similar site.)

2. Accurately identify and record [illegible] coverages for all indicator species [illegible]

3. Check plot site in the field to verify that the plot is representative of the stand as a whole. If not, take another plot.

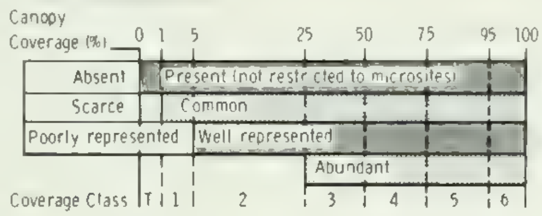
4. Identify the correct potential climax tree species in the SERIES key. Generally, a tree species is considered reproducing successfully if [illegible] or more individuals per acre [illegible] will [illegible] the site.

5. Within the appropriate series, key to HABITAT TYPE by following the key literally. Determine PHASE [illegible] the stand [illegible] with the phase descriptions for the type. (The first phase description that fits the stand is the correct one.)

6. Use the definitions diagrammed below for [illegible] coverage terms in the key. If [illegible] difficult [illegible] between types, refer to [illegible] data in Appendix [illegible] and the habitat type descriptions.

7. In stands where undergrowth [illegible] depauperate [illegible] small, sparse [illegible] dense shading or duff accumulation, [illegible] definitions of the [illegible] coverage classes [illegible] well represented [illegible] common [illegible]

8. Remember, the key is [illegible] the [illegible] determinate [illegible] the written description.



KEY TO CLIMAX SERIES

[illegible] Read the Instructions

1. Abies grandis present and reproducing more successfully than [illegible] ABIES GRANDIS SERIES [illegible]
1. Abies grandis not the indicated climax
2. Abies lasiocarpa present and reproducing successfully ABIES LASIOCARPA SERIES [illegible]
2. Abies lasiocarpa not the indicated climax 3
3. Picea engelmannii present and reproducing successfully PICEA ENGELMANNII SERIES [illegible]
3. Picea engelmannii not the indicated climax 4
4. Pinus flexilis [illegible] successfully reproducing dominant in [illegible] stands, often sharing that status with Pseudotsuga PINUS FLEXILIS SERIES [illegible]
4. Pinus flexilis absent [illegible]
5. Pseudotsuga menziesii present and reproducing successfully PSEUDOTSUGA MENZIESII SERIES [illegible]
5. Pseudotsuga menziesii not the indicated climax 6
6. Pinus albicaulis well represented and reproducing successfully PINUS ALBICAULIS SERIES [illegible]
6. Pinus albicaulis not the indicated successional dominant 7
7. Pinus contorta dominant and reproducing successfully PINUS CONTORTA SERIES [illegible]
7. Pinus contorta not the indicated successional dominant
8. Pinus ponderosa present and reproducing [illegible] PINUS PONDEROSA SERIES [illegible]
8. Pinus ponderosa not the indicated climax 9
9. Populus tremuloides the indicated dominant POPULUS TREMULOIDES SERIES [illegible]
9. Populus tremuloides not the indicated dominant [illegible]

A. Key to Pinus flexilis Habitat Types

1. Juniperus communis well represented PINUS FLEXILIS/JUNIPERUS COMMUNIS h.t.* [illegible]
1. J. communis poorly represented 2
2. Cercocarpus ledifolius is well represented PINUS FLEXILIS/CERCOCARPUS LEDIFOLIUS h.t.* [illegible]
2. C. ledifolius poorly represented 3
3. Festuca idahoensis well represented PINUS FLEXILIS/FESTUCA IDAHOENSIS h.t. [illegible]
3. F. idahoensis poorly represented, Hesperochloa kingii (Leucopoa kingii) common PINUS FLEXILIS/HESPEROCHLOA KINGII* h.t. [illegible]

B. Key to Pinus ponderosa Habitat Types

1. Physocarpus malvaceus well represented PINUS PONDEROSA/PHYSOCARPUS MALVACEUS h.t.* [illegible]
1. P. malvaceus poorly represented
2. Symphoricarpos albus well represented PINUS PONDEROSA/SYMPHORICARPOS ALBUS h.t. [illegible]
2. S. albus poorly represented 3
3. Symphoricarpos oreophilus or Prunus virginiana well represented PINUS PONDEROSA/SYMPHORICARPOS OREOPHILUS h.t. [illegible]
3. S. oreophilus and P. virginiana poorly represented 4
4. Purshia tridentata well represented PINUS PONDEROSA/PURSHIA TRIDENTATA h.t. [illegible]
4a. Festuca idahoensis well represented FESTUCA IDAHOENSIS phase
4b. F. idahoensis poorly represented AGROPYRON SPICATUM phase
4. P. tridentata poorly represented 5
5. Festuca idahoensis well represented PINUS PONDEROSA/FESTUCA IDAHOENSIS h.t. [illegible]
5. F. idahoensis poorly represented 6
6. Agropyron spicatum well represented on sites in good condition PINUS PONDEROSA/AGROPYRON SPICATUM h.t. [illegible]
6. A. spicatum poorly represented on sites in good condition and Stipa spp. well represented PINUS PONDEROSA/STIPA OCCIDENTALIS h.t. [illegible]

*h.t.s and phases incidental to central Idaho and omitted from charts and tables

C. Key to *Pseudotsuga menziesii* Habitat Types

1.	*Vaccinium caespitosum* common	PSEUDOTSUGA MENZIESII/VACCINIUM CAESPITOSUM h.t.* (p. [illegible])
1.	*V. caespitosum* scarce	2
2.	*Linnaea borealis* common	PSEUDOTSUGA MENZIESII/LINNAEA BOREALIS h.t.* (p. [illegible])
2.	*L. borealis* scarce	3
3.	*Physocarpus malvaceus* and/or *Holodiscus discolor* well represented	PSEUDOTSUGA MENZIESII/PHYSOCARPUS MALVACEUS h.t. (p. [illegible])
3a.	*Pinus ponderosa* present or potentially present	
a.	*Calamagrostis rubescens* and/or *Carex geyeri* dominant, *Physocarpus* forming only a broken, patchy cover	CALAMAGROSTIS RUBESCENS phase*
b.	Not as above	PINUS PONDEROSA phase
3b.	*P. ponderosa* absent and unable to establish	PSEUDOTSUGA MENZIESII phase
3.	*P. malvaceus* and *H. discolor* poorly represented	4
4.	*Acer glabrum* well represented	PSEUDOTSUGA MENZIESII/ACER GLABRUM h.t. (p. [illegible])
4a.	*Penstemon wilcoxii* and/or *Clematis columbiana* usually present, sites mainly west of the Big Wood River	ACER GLABRUM phase
4b.	*Pinus flexilis* usually present, sites mainly east of the Big Wood River	SYMPHORICARPOS OREOPHILUS phase
4.	*A. glabrum* poorly represented	5
5.	*Vaccinium globulare* or *Xerophyllum tenax* well represented	PSEUDOTSUGA MENZIESII/VACCINIUM GLOBULARE h.t.* (p. [illegible])
5.	*V. globulare* and *X. tenax* poorly represented	6
6.	*Symphoricarpos albus* well represented	PSEUDOTSUGA MENZIESII/SYMPHORICARPOS ALBUS h.t. (p. [illegible])
6a.	*Pinus ponderosa* present or potentially present	PINUS PONDEROSA phase
6b.	*P. ponderosa* absent and unable to establish	SYMPHORICARPOS ALBUS phase
6.	*S. albus* poorly represented	7
7.	*Spiraea betulifolia* or *S. pyramidata* well represented	PSEUDOTSUGA MENZIESII/SPIRAEA BETULIFOLIA h.t. (p. [illegible])
7a.	*Pinus ponderosa* present or potentially present	PINUS PONDEROSA phase
7b.	*Calamagrostis rubescens* well represented	CALAMAGROSTIS RUBESCENS phase
7c.	Not as above in 7a or 7b	SPIRAEA BETULIFOLIA phase
7.	*S. betulifolia* and *S. pyramidata* poorly represented	8
8.	*Osmorhiza chilensis* well represented	PSEUDOTSUGA MENZIESII/OSMORHIZA CHILENSIS h.t. (p. [illegible])
8.	*O. chilensis* poorly represented	9
9.	*Calamagrostis rubescens* well represented	PSEUDOTSUGA MENZIESII/CALAMAGROSTIS RUBESCENS h.t. (p. [illegible])
9a.	*Pinus ponderosa* present or potentially present	PINUS PONDEROSA phase
9b.	*P. ponderosa* absent and unable to establish, *Festuca idahoensis* well represented	FESTUCA IDAHOENSIS phase
9c.	Not as above in 9a or 9b	CALAMAGROSTIS RUBESCENS phase
9.	*C. rubescens* poorly represented	10
10.	*Cercocarpus ledifolius* well represented and the indicated climax dominant shrub	PSEUDOTSUGA MENZIESII/CERCOCARPUS LEDIFOLIUS h.t. (p. [illegible])
10.	*C. ledifolius* poorly represented or seral	11
11.	*Berberis repens* well represented	PSEUDOTSUGA MENZIESII/BERBERIS REPENS h.t. (p. [illegible])
11a.	*Carex geyeri* abundant	CAREX GEYERI phase
11b.	*C. geyeri* not abundant, *Symphoricarpos oreophilus* abundant, stands never achieving closed canopies	SYMPHORICARPOS OREOPHILUS phase
11c.	*S. oreophilus* not abundant, stands eventually achieving closed canopies	BERBERIS REPENS phase
11.	*B. repens* poorly represented	12
12.	*Carex geyeri* well represented	PSEUDOTSUGA MENZIESII/CAREX GEYERI h.t. (p. [illegible])
12a.	*Pinus ponderosa* present or potentially present	PINUS PONDEROSA phase
12b.	*P. ponderosa* absent and unable to establish, *Symphoricarpos oreophilus* or *Artemisia tridentata* well represented	SYMPHORICARPOS OREOPHILUS phase
12c.	Not as above in 12a or 12b	CAREX GEYERI phase
12.	*C. geyeri* poorly represented	13
13.	*Juniperus communis* well represented	PSEUDOTSUGA MENZIESII/JUNIPERUS COMMUNIS h.t. (p. [illegible])
13.	*J. communis* poorly represented	14
14.	*Arnica cordifolia* or *Astragalus miser* well represented or a dominant forb of normally depauperate undergrowths	PSEUDOTSUGA MENZIESII/ARNICA CORDIFOLIA h.t. (p. [illegible])
14a.	*Arnica cordifolia* well represented	ARNICA CORDIFOLIA phase
14b.	*A. cordifolia* poorly represented, *Astragalus miser* well represented	ASTRAGALUS MISER phase
14.	*A. cordifolia* and *A. miser* poorly represented or not a dominant forb	15
15.	*Symphoricarpos oreophilus*, *Ribes cereum* or *Prunus virginiana* well represented	PSEUDOTSUGA MENZIESII/SYMPHORICARPOS OREOPHILUS h.t. (p. [illegible])
15.	*S. oreophilus*, *R. cereum* and *P. virginiana* poorly represented	16
16.	*Festuca idahoensis* well represented	PSEUDOTSUGA MENZIESII/FESTUCA IDAHOENSIS h.t. (p. [illegible])
16a.	*Pinus ponderosa* present	PINUS PONDEROSA phase
16b.	*P. ponderosa* absent	FESTUCA IDAHOENSIS phase
16.	*F. idahoensis* poorly represented; *Agropyron spicatum* or *Melica bulbosa* well represented on sites in good condition	PSEUDOTSUGA MENZIESII/AGROPYRON SPICATUM h.t. (p. [illegible])

D. Key to *Picea engelmannii* Habitat Types

1.	*Equisetum arvense* abundant	PICEA ENGELMANNII/EQUISETUM ARVENSE h.t.* (p. [illegible])
1.	*E. arvense* not abundant	2
2.	*Carex disperma* well represented	PICEA ENGELMANNII/CAREX DISPERMA h.t. (p. [illegible])
2.	*C. disperma* poorly represented	3
3.	*Galium triflorum*, *Actaea rubra* or *Streptopus amplexifolius* common either individually or collectively	PICEA ENGELMANNII/GALIUM TRIFLORUM h.t.* (p. [illegible])
3.	Not as above, *Hypnum revolutum* (a prostrate moss) well represented	PICEA ENGELMANNII/HYPNUM REVOLUTUM h.t. (p. [illegible])

*h.t.s and phases incidental to central Idaho and omitted from charts and tables

E. Key to *Abies grandis* Habitat Types

1. Clintonia uniflora present . . . ABIES GRANDIS/CLINTONIA UNIFLORA h.t. (p. [illegible])
1. C. uniflora absent . . . 2

2. Coptis occidentalis common . . . ABIES GRANDIS/COPTIS OCCIDENTALIS h.t.* (p. [illegible])
2. C. occidentalis scarce . . . 3

3. Vaccinium caespitosum common . . . ABIES GRANDIS/VACCINIUM CAESPITOSUM h.t. (p. [illegible])
3. V. caespitosum scarce . . . 4

4. Linnaea borealis common . . . ABIES GRANDIS/LINNAEA BOREALIS h.t. (p. [illegible])
   - 4a. Xerophyllum tenax common . . . XEROPHYLLUM TENAX phase*
   - 4b. X. tenax scarce, Vaccinium globulare well represented . . . VACCINIUM GLOBULARE phase
   - 4c. Not as above in 4a or 4b . . . LINNAEA BOREALIS phase
4. L. borealis scarce . . . 5

5. Acer glabrum, Physocarpus malvaceus or Holodiscus discolor well represented. If only common then Adenocaulon bicolor or Disporum trachycarpum present . . . ABIES GRANDIS/ACER GLABRUM h.t. (p. [illegible])
   - 5a. Acer glabrum well represented, if only common then at least more prevalent than Physocarpus and Holodiscus . . . ACER GLABRUM phase
   - 5b. A. glabrum poorly represented and less prevalent than Physocarpus and Holodiscus . . . PHYSOCARPUS MALVACEUS phase
5. Not as above . . . 6

6. Xerophyllum tenax well represented . . . ABIES GRANDIS/XEROPHYLLUM TENAX h.t.*
6. X. tenax poorly represented . . . 7

7. Vaccinium globulare well represented . . . ABIES GRANDIS/VACCINIUM GLOBULARE h.t.
7. V. globulare poorly represented . . . 8

8. Spiraea betulifolia or Lathyrus nevadensis well represented . . . ABIES GRANDIS/SPIRAEA BETULIFOLIA h.t.
8. S. betulifolia and L. nevadensis poorly represented, Calamagrostis rubescens well represented . . . ABIES GRANDIS/CALAMAGROSTIS RUBESCENS h.t. (p. [illegible])

F. Key to *Pinus contorta* Communities

1. Calamagrostis canadensis or Ledum glandulosum well represented . . . ABIES LASIOCARPA/CALAMAGROSTIS CANADENSIS h.t. (p. [illegible])
1. C. canadensis and L. glandulosum poorly represented . . . 2

2. Streptopus amplexifolius, Senecio triangularis, Ligusticum canbyi or Trautvetteria caroliniensis well represented either individually or collectively . . . ABIES LASIOCARPA/STREPTOPUS AMPLEXIFOLIUS h.t. (p. [illegible])
2. Not as above . . . 3

3. Clintonia uniflora present . . . ABIES LASIOCARPA/CLINTONIA UNIFLORA h.t. (p. [illegible])
3. C. uniflora absent . . . 4

4. Coptis occidentalis common . . . ABIES LASIOCARPA/COPTIS OCCIDENTALIS h.t.* (p. [illegible]) or ABIES GRANDIS/COPTIS OCCIDENTALIS h.t.* (p. [illegible])
4. C. occidentalis scarce . . . 5

5. Menziesia ferruginea well represented . . . ABIES LASIOCARPA/MENZIESIA FERRUGINEA h.t. (p. [illegible])
5. M. ferruginea poorly represented . . . 6

6. Vaccinium caespitosum common . . . PINUS CONTORTA/VACCINIUM CAESPITOSUM c.t. (p. [illegible])
6. V. caespitosum scarce . . . 7

7. Linnaea borealis common . . . ABIES LASIOCARPA/LINNAEA BOREALIS h.t. (p. [illegible]) or ABIES GRANDIS/LINNAEA BOREALIS h.t. (p. [illegible])
7. L. borealis scarce . . . 8

8. Alnus sinuata well represented . . . ABIES LASIOCARPA/ALNUS SINUATA h.t.* (p. [illegible])
8. A. sinuata poorly represented . . . 9

9. Xerophyllum tenax well represented . . . ABIES LASIOCARPA/XEROPHYLLUM TENAX h.t. (p. [illegible]) or ABIES GRANDIS/XEROPHYLLUM TENAX h.t. (p. [illegible])
9. X. tenax poorly represented . . . 10

10. Vaccinium globulare well represented . . . ABIES LASIOCARPA/VACCINIUM GLOBULARE h.t. (p. 70) or ABIES GRANDIS/VACCINIUM GLOBULARE h.t. (p. [illegible])
10. V. globulare poorly represented . . . 11

11. Spiraea betulifolia well represented . . . ABIES LASIOCARPA/SPIRAEA BETULIFOLIA h.t. (p. [illegible]) or PSEUDOTSUGA MENZIESII/SPIRAEA BETULIFOLIA h.t. (p. [illegible])
11. S. betulifolia poorly represented . . . 12

12. Luzula hitchcockii common . . . ABIES LASIOCARPA/LUZULA HITCHCOCKII h.t. (p. [illegible])
12. L. hitchcockii scarce . . . 13

13. Vaccinium scoparium well represented . . . PINUS CONTORTA/VACCINIUM SCOPARIUM c.t. (p. 85)
13. V. scoparium poorly represented . . . 14

14. Calamagrostis rubescens well represented . . . ABIES LASIOCARPA/CALAMAGROSTIS RUBESCENS h.t. (p. [illegible]) or PSEUDOTSUGA MENZIESII/CALAMAGROSTIS RUBESCENS h.t. (p. [illegible])
14. C. rubescens poorly represented . . . 15

15. Carex geyeri well represented . . . PINUS CONTORTA/CAREX GEYERI c.t. (p. 85)
15. C. geyeri poorly represented . . . 16

16. Juniperus communis well represented . . . ABIES LASIOCARPA/JUNIPERUS COMMUNIS h.t. (p. 78) or PSEUDOTSUGA MENZIESII/JUNIPERUS COMMUNIS h.t. (p. [illegible])
16. J. communis poorly represented . . . 17

17. Arnica cordifolia well represented or the dominant forb of normally depauperate undergrowths . . . ABIES LASIOCARPA/ARNICA CORDIFOLIA h.t. (p. [illegible]) or PSEUDOTSUGA MENZIESII/ARNICA CORDIFOLIA h.t. (p. [illegible])
17. Not as above, Festuca idahoensis common . . . PINUS CONTORTA/FESTUCA IDAHOENSIS h.t. (p. 85)

*h.t.s and phases incidental to central Idaho and omitted from charts and tables

Key to *Abies lasiocarpa* Habitat Types

1. *Caltha biflora* common .... ABIES LASIOCARPA/CALTHA BIFLORA h.t. [illegible]
1. *C. biflora* scarce 2

2. *Equisetum arvense* abundant .... PICEA ENGELMANNII/EQUISETUM ARVENSE h.t.* [illegible]
2. *E. arvense* not abundant 3

3. *Carex disperma* well represented .... PICEA ENGELMANNII/CAREX DISPERMA h.t. [illegible]
3. *C. disperma* poorly represented 4

4. *Calamagrostis canadensis* or *Ledum glandulosum* well represented .... ABIES LASIOCARPA/CALAMAGROSTIS CANADENSIS h.t. [illegible]
   - 4a. *Ledum glandulosum* well represented .... LEDUM GLANDULOSUM phase
   - 4b. Not as above in 4a; *Vaccinium caespitosum* common .... VACCINIUM CAESPITOSUM phase
   - 4c. Not as above in 4a or 4b; *Ligusticum canbyi* or *Trautvetteria caroliniensis* present .... LIGUSTICUM CANBYI phase
   - 4d. Not as above in 4a, 4b, or 4c .... CALAMAGROSTIS CANADENSIS phase
4. *C. canadensis* and *L. glandulosum* poorly represented 5

5. *Streptopus amplexifolius*, *Senecio triangularis*, *Ligusticum canbyi*, or *Trautvetteria caroliniensis* well represented either individually or collectively .... ABIES LASIOCARPA/STREPTOPUS AMPLEXIFOLIUS h.t. [illegible]
   - 5a. *Ligusticum canbyi* or *Trautvetteria caroliniensis* present .... LIGUSTICUM CANBYI phase
   - 5b. *L. canbyi* and *T. caroliniensis* absent .... STREPTOPUS AMPLEXIFOLIUS phase
5. Not as above 6

6. *Clintonia uniflora* present .... ABIES LASIOCARPA/CLINTONIA UNIFLORA h.t. [illegible]
   - 6a. *Menziesia ferruginea* well represented .... MENZIESIA FERRUGINEA phase*
   - 6b. *M. ferruginea* poorly represented .... CLINTONIA UNIFLORA phase
6. *C. uniflora* absent 7

7. *Coptis occidentalis* common .... ABIES LASIOCARPA/COPTIS OCCIDENTALIS h.t.* [illegible]
7. *C. occidentalis* scarce 8

8. *Menziesia ferruginea* well represented .... ABIES LASIOCARPA/MENZIESIA FERRUGINEA h.t. [illegible]
   - 8a. *Luzula hitchcockii* common .... LUZULA HITCHCOCKII phase*
   - 8b. *L. hitchcockii* scarce .... MENZIESIA FERRUGINEA phase
8. *M. ferruginea* poorly represented 9

9. *Acer glabrum* well represented .... ABIES LASIOCARPA/ACER GLABRUM h.t. [illegible]
9. *A. glabrum* poorly represented 10

10. *Vaccinium caespitosum* common .... ABIES LASIOCARPA/VACCINIUM CAESPITOSUM h.t. [illegible]
10. *V. caespitosum* scarce 11

11. *Linnaea borealis* common .... ABIES LASIOCARPA/LINNAEA BOREALIS h.t. [illegible]
    - 11a. *Xerophyllum tenax* well represented .... XEROPHYLLUM TENAX phase*
    - 11b. *X. tenax* poorly represented, *Vaccinium scoparium* well represented .... VACCINIUM SCOPARIUM phase*
    - 11c. Not as above in 11a or 11b .... LINNAEA BOREALIS phase
11. *L. borealis* scarce 12

12. *Alnus sinuata* well represented .... ABIES LASIOCARPA/ALNUS SINUATA h.t.* [illegible]
12. *A. sinuata* poorly represented 13

13. *Xerophyllum tenax* well represented .... ABIES LASIOCARPA/XEROPHYLLUM TENAX h.t. [illegible]
    - 13a. *Vaccinium globulare* or *Spiraea betulifolia* well represented .... VACCINIUM GLOBULARE phase
    - 13b. Not as above in 13a; *Luzula hitchcockii* common .... LUZULA HITCHCOCKII phase
    - 13c. Not as above in 13a or 13b; *Vaccinium scoparium* usually abundant .... VACCINIUM SCOPARIUM phase*
13. *X. tenax* poorly represented 14

14. *Vaccinium globulare* well represented .... ABIES LASIOCARPA/VACCINIUM GLOBULARE h.t. [illegible]
    - 14a. *Vaccinium scoparium* abundant .... VACCINIUM SCOPARIUM phase*
    - 14b. *V. scoparium* not abundant .... VACCINIUM GLOBULARE phase
14. *V. globulare* poorly represented 15

15. *Spiraea betulifolia* well represented .... ABIES LASIOCARPA/SPIRAEA BETULIFOLIA h.t. [illegible]
15. *S. betulifolia* poorly represented 16

16. *Luzula hitchcockii* common .... ABIES LASIOCARPA/LUZULA HITCHCOCKII h.t. [illegible]
    - 16a. *Vaccinium scoparium* well represented .... VACCINIUM SCOPARIUM phase
    - 16b. Not as above in 16a; *Luzula hitchcockii* well represented .... LUZULA HITCHCOCKII phase
    - 16c. Not as above in 16a or 16b
16. *L. hitchcockii* scarce 17

17. *Vaccinium scoparium* well represented .... ABIES LASIOCARPA/VACCINIUM SCOPARIUM h.t. [illegible]
    - 17a. *Calamagrostis rubescens* well represented .... CALAMAGROSTIS RUBESCENS phase
    - 17b. Not as above in 17a; *Pinus albicaulis* well represented .... PINUS ALBICAULIS phase
    - 17c. Not as above in 17a or 17b .... VACCINIUM SCOPARIUM phase
17. *V. scoparium* poorly represented 18

18. *Calamagrostis rubescens* well represented .... ABIES LASIOCARPA/CALAMAGROSTIS RUBESCENS h.t. [illegible]
18. *C. rubescens* poorly represented 19

19. *Carex geyeri* well represented .... ABIES LASIOCARPA/CAREX GEYERI h.t. [illegible]
    - 19a. *Artemisia tridentata* well represented .... ARTEMISIA TRIDENTATA phase
    - 19b. *A. tridentata* poorly represented .... CAREX GEYERI phase
19. *C. geyeri* poorly represented 20

20. *Juniperus communis* well represented .... ABIES LASIOCARPA/JUNIPERUS COMMUNIS h.t. [illegible]
20. *J. communis* poorly represented 21

21. *Ribes montigenum* well represented or the dominant plant of normally depauperate undergrowths .... ABIES LASIOCARPA/RIBES MONTIGENUM h.t. [illegible]
21. Not as above 22

22. *Arnica cordifolia* well represented or a dominant forb of normally depauperate undergrowths .... ABIES LASIOCARPA/ARNICA CORDIFOLIA h.t. [illegible]
22. Not as above; *Pinus albicaulis* usually well represented and *Abies lasiocarpa* often stunted .... PINUS ALBICAULIS - ABIES LASIOCARPA h.t. [illegible]

*H.t.s and phases incidental to central Idaho and omitted from charts and tables.

NORTHERN IDAHO & EASTERN WASH. R&J DAUBENMIRE 1968	BOISE & PAYETTE N.F. PFISTER & OTHERS 1973	CHALLIS, SALMON, & SAWTOOTH N.F. STEELE & OTHERS 1974	CENTRAL IDAHO REVIEW DRAFT STEELE & OTHERS 1975	CENTRAL IDAHO H.T.S.
PIPO/ STCO			PIPO/ STOC	PIPO/ STOC
PIPO/ AGSP	PIPO/ AGSP	PIPO/ AGSP	PIPO/ AGSP	PIPO/ AGSP
PIPO/ FEID	PIPO/ FEID	PIPO/ FEID	PIPO/ FEID	PIPO/ FEID
			PIPO/ PUTR AGSP	PIPO/ PUTR AGSP
PIPO/ PUTR	PIPO/ PUTR	PIPO/ PUTR	PIPO/ PUTR FEID	PIPO/ PUTR FEID
	PIPO/ PRVI		PIPO/ SYOR	PIPO/ SYOR
PIPO/ SYAL	PIPO/ SYAL	PIPO/ SYAL	PIPO/ SYAL	PIPO/ SYAL
PIPO/ PHMA	PIPO/ PHMA		PIPO/ PHMA	PIPO/ PHMA
		PIFL/ FEID	PIFL/ FEID	PIFL/ FEID
	PSME/ AGSP	PSME/ AGSP	PSME/ AGSP	PSME/ AGSP
	PSME/ SYOR (IN PART)	PSME/ SYOR SYOR	PSME/ SYOR SYOR	PSME/ SYOR
	PSME/ PRVI (IN PART)	PSME/ SYOR PRVI	PSME/ SYOR PRVI	
	PSME/ FEID	PSME/ FEID	PSME/ FEID	PSME/ FEID FEID PIPO
		PSME/ CELE	PSME/ CELE	PSME/ CELE
		PSME/ ARCO	PSME/ ARCO	PSME/ ARCO ASMI ARCO
		PSME/ OSCH	PSME/ OSCH	PSME/ OSCH
		PSME/ JUCO	PSME/ JUCO	PSME/ JUCO
				PSME/ BERE SYOR CAGE BERE
	PSME/ SYOR (IN PART) PSME/ PRVI (IN PART)	PSME/ CAGE SYOR	PSME/ CAGE SYOR	PSME/ CAGE SYOR
	PSME/ CAGE ARTR	PSME/ CAGE ARTR	PSME/ CAGE ARTR	
	PSME/ CAGE CAGE	PSME/ CAGE CAGE	PSME/ CAGE CAGE	PSME/ CAGE PIPO CAGE
PSME/ CARU CARU	PSME/ SYOR (IN PART) PSME/ PRVI (IN PART) PSME/ CARU	PSME/ CARU SYOR PSME/ CARU CARU PSME/ CARU ARUV	PSME/ CARU CARU PSME/ CARU ARUV	PSME/ CARU PIPO FEID CARU
PSME/ CARU ARUV				
	PSME/ SPBE CAGE	PSME/ SPBE CAGE	PSME/ SPBE CAGE	PIPO
	PSME/ SPBE CARU	PSME/ SPBE CARU	PSME/ SPBE CARU	PSME/ SPBE CARU
	PSME/ SPBE SPBE	PSME/ SPBE SPBE	PSME/ SPBE SPBE	SPBE
		PSME/ SYAL SYAL	PSME/ SYAL SYAL	PIPO
PSME/ SYAL	PSME/ SYAL	PSME/ SYAL ARUV	PSME/ SYAL ARUV	PSME/ SYAL SYAL
			PSME/ VAGL	PSME/ VAGL
	PSME/ ACGL	PSME/ ACGL	PSME/ ACGL	PSME/ ACGL SYOR ACGL
	PSME/ XETE	PSME/ XETE	PSME/ XETE	
			PSME/ PHMA ACGL	PIPO
PSME/ PHMA	PSME/ PHMA	PSME/ PHMA	PSME/ PHMA PHMA	PSME/ PHMA PSME
			PSME/ PHMA CARU	PSME/ PHMA CARU
				PSME/ LIBO
				PSME/ VACA
		PIEN/ CADI	PIEN/ CADI	PIEN/ EQAR PIEN/ CADI
		UNCLASSIFIED COMMUNITIES	UNCLASSIFIED COMMUNITIES	PIEN/ GATR
				PIEN/ HYRE

Figure 46. — Relationships of central Idaho habitat types to previous classifications in Idaho. con

Figure 46. — con

NORTHERN IDAHO & EASTERN WASH. R & J DAUBENMIRE 1968	BOISE & PAYETTE N.F. PFISTER & OTHERS 1973	CHALLIS, SALMON, & SAWTOOTH N.F. STEELE & OTHERS 1974	CENTRAL IDAHO REVIEW DRAFT STEELE & OTHERS 1975	CENTRAL IDAHO H.T.S.
				ABGR/CARU
	ABGR/ SPBE (IN PART)		ABGR/ SPBE	ABGR/ SPBE
	ABGR/ VAGL (IN PART)	ABGR/ VAGL (IN PART)	ABGR/ VAGL	ABGR/ VAGL
			ABGR/ XETE	ABGR/ XETE
	ABGR/SPBE (IN PART) ABGR/VAGL (IN PART)	ABGR/ VAGL (IN PART)	ABGR/ ACGL	ABGR/ ACGL PHMA ACGL
ABGR/PAMY (IN PART ?)	ABGR/ VAGL (IN PART)	ABGR/ VAGL (IN PART)	ABGR/ LIBO VAGL	ABGR/ LIBO VAGL
				ABGR/ LIBO XETE
			ABGR/ COOC	ABGR/ COOC
ABGR/ PAMY	ABGR/ CLUN	ABGR/ CLUN	ABGR/ CLUN	ABGR/ CLUN
	ABLA/ CABI	ABLA/ CABI	ABLA/ CABI	ABLA/ CABI
ABLA/ PAMY (IN PART)	ABLA/ CLUN		ABLA/ CLUN	ABLA/ CLUN
ABLA/ MEFE	ABLA/ MEFE	ABLA/ MEFE	ABLA/ MEFE	ABLA/ MEFE
	ABLA/ VACA CACA	ABLA/ VACA CACA	ABLA/ VACA CACA	ABLA/ CACA VACA
	ABLA/ VACA VACA	ABLA/ VACA VACA	ABLA/ VACA VACA	ABLA/ VACA
	ABLA/ CACA LICA		ABLA/ CACA LICA	ABLA/ CACA LICA
	ABLA/ CACA CACA	ABLA/ CACA	ABLA/ CACA CACA	ABLA/ CACA CACA
	ABLA/ LICA	ABLA/ STAM	ABLA/ STAM	ABLA/ STAM LICA STAM
ABLA/ PAMY (IN PART)	ABLA/ VAGL (IN PART)		ABLA/ LIBO LIBO	ABLA/ LIBO LIBO
				ABLA/ LIBO XETE
		ABLA/ LIBO	ABLA/ LIBO VASC	ABLA/ LIBO VASC
	ABLA/ LEGL	ABLA/ LEGL	ABLA/ LEGL	ABLA/ CACA LEGL
	ABLA/ ACGL	ABLA/ ACGL	ABLA/ ACGL	ABLA/ ACGL
	ABLA/ XETE VAGL	ABLA/ XETE VAGL	ABLA/ XETE VAGL	ABLA/ XETE VAGL
ABLA/ XETE	ABLA/ XETE XETE	ABLA/ XETE XETE	ABLA/ XETE XETE	ABLA/ XETE VASC
				ABLA/ XETE LUHI
ABLA/ PAMY (IN PART)	ABLA/ VAGL (IN PART)	ABLA/ VAGL	ABLA/ VAGL	ABLA/ VAGL VASC VAGL
	ABLA/ SPBE	ABLA/ SPBE	ABLA/ SPBE	ABLA/ SPBE
	ABLA/ LUHI VASC		ABLA/ LUHI VASC	ABLA/ LUHI VASC
	ABLA/ LUHI LUHI		ABLA/ LUHI LUHI	ABLA/ LUHI LUHI
		ABLA/ VASC CARU	ABLA/ VASC CARU	ABLA/ VASC CARU
ABLA/ VASC	ABLA/ VASC	ABLA/ VASC VASC	ABLA/ VASC VASC	ABLA/ VASC VASC
				ABLA/ VASC PIAL
	ABLA/ CARU	ABLA/ CARU	ABLA/ CARU	ABLA/ CARU
		ABLA/ CAGE CAGE		
	ABLA/ CAGE CAGE	ABLA/ CAGE SYOR	ABLA/ CAGE CAGE	ABLA/ CAGE CAGE
	ABLA/ CAGE ARTR	ABLA/ CAGE ARTR	ABLA/ CAGE ARTR	ABLA/ CAGE ARTR
		ABLA/ JUCO	ABLA/ JUCO	ABLA/ JUCO
		ABLA/ RIMO	ABLA/ RIMO	ABLA/ RIMO
		ABLA/ ARCO	ABLA/ ARCO	ABLA/ ARCO
PIAL-ABLA	ABLA/ PIAL	PIAL-ABLA	PIAL-ABLA	PIAL-ABLA H. T. S.
			PIAL	PIAL H. T. S.
	PICO/ FEID	PICO/ FEID	PICO/ FEID	PICO/ FEID

APPENDIX F. CENTRAL IDAHO HABITAT TYPE FIELD FORM

Central Idaho habitat type field form

Name				
Date				
Plot No.				
Location				
T. R.				
Section				
Elevation				
Aspect				
Slope (%)				
Topography				
Configuration				

(Code Description)

Topography:	Horizontal Configuration:	Vegetation Coverage Class:	
1-Ridge	1-Convex (Dry)	0-None	3-25 to 50%
2-Upper Slope	2-Straight	T-Rare to 1%	4-50 to 75%
3-Mid Slope	3-Concave (wet)	1-1 to 5%	5-75 to 95%
4-Lower Slope	4-Undulating	2-5 to 25%	6-95 to 100%
5-Bench or Flat			
6-Streambottom			

Note: Rate trees (>4") and regen (0-4") separately (e.g. 4/2)

TREES	Abbrev.	Common Name	Canopy	Coverage	Class
1. Abies grandis	ABGR	grand fir	/	/	/
2. Abies lasiocarpa	ABLA	subalpine fir	/	/	/
3. Larix occidentalis	LAOC	western larch	/	/	/
4. Picea engelmannii	PIEN	Engelmann spruce	/	/	/
5. Pinus albicaulis	PIAL	whitebark pine	/	/	/
6. Pinus contorta	PICO	lodgepole pine	/	/	/
7. Pinus flexilis	PIFL	limber pine	/	/	/
8. Pinus ponderosa	PIPO	ponderosa pine	/	/	/
9. Pseudotsuga menziesii	PSME	Douglas-fir	/	/	/
10. Populus tremuloides	POTR	quaking aspen	/	/	/
SHRUBS AND VINES					
1. Acer glabrum	ACGL	mountain maple			
2. Alnus sinuata	ALSI	mountain alder			
3. Artemisia tridentata	ARTR	big sagebrush			
4. Berberis repens (+ aquifolium)	BERE	Oregon grape			
5. Cercocarpus ledifolius	CELE	curl-leaf mountain-mahogany			
6. Clematis columbiana	CLCO	rock clematis			
7. Holodiscus discolor	HODI	ocean-spray			
8. Juniperus communis	JUCO	common juniper			
9. Ledum glandulosum	LEGL	Labrador tea			
10. Linnaea borealis	LIBO	twinflower			
11. Menziesia ferruginea	MEFE	menziesia			
12. Physocarpus malvaceus	PHMA	ninebark			
13. Prunus virginiana	PRVI	chokecherry			
14. Purshia tridentata	PUTR	bitterbrush			
15. Ribes cereum	RICE	squaw current			
16 Ribes montigenum	RIMO	mountain gooseberry			
17. Spiraea betulifolia (+ pyramidata)	SPBE	white spirea			
18. Symphoricarpos albus	SYAL	common snowberry			
19. Symphoricarpos oreophilus	SYOR	mountain snowberry			
20. Vaccinium caespitosum	VACA	dwarf huckleberry			
21. Vaccinium globulare (+ membranaceum)	VAGL	blue huckleberry			
22. Vaccinium scoparium (+ myrtillus)	VASC	grouse whortleberry			
GRAMINOIDS					
1. Agropyron spicatum	AGSP	bluebunch wheatgrass			
2. Calamagrostis rubescens	CARU	pinegrass			
3. Calamagrostis canadensis	CACA	bluejoint			
4. Carex disperma	CADI	soft-leaved sedge			
5. Carex geyeri	CAGE	elk sedge			
6. Festuca idahoensis	FEID	Idaho fescue			
7. Hesperochloa kingii	HEKI	spikefescue			
8. Luzula hitchcockii	LUHI	smooth woodrush			
9. Stipa occidentalis	STOC	western needlegrass			
FORBS, FERNS, AND FERN ALLIES					
1. Actaea rubra	ACRU	baneberry			
2. Adenocaulon bicolor	ADBI	trail-plant			
3. Arnica cordifolia	ARCO	heartleaf arnica			
4. Astragalus miser	ASMI	weedy milkvetch			
5. Caltha biflora	CABI	twinflower marsh marigold			
6. Clintonia uniflora	CLUN	queencup beadlily			
7. Coptis occidentalis	COOC	western goldthread			
8. Disporum trachycarpum	DITR	sierra fairybell			
9. Equisetum arvense	EQAR	common horsetail			
10. Lathyrus nevadensis cusickii	LANC	Cusick's peavine			
11. Ligusticum canbyi	LICA	Canby's ligusticum			
12. Osmorhiza chilensis	OSCH	mountain sweet-root			
13. Penstemon wilcoxii	PEWI	Wilcox's penstemon			
14. Senecio triangularis	SETR	arrowleaf groundsel			
15. Streptopus amplexifolius	STAM	twisted stalk			
16. Trautvetteria caroliniensis	TRCA	false bugbane			
17. Xerophyllum tenax	XETE	beargrass			

Series			
Habitat type			
Phase			

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 273 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

Field programs and research work units of the Station are maintained in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

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Forest Service

**Intermountain
Forest and Range
Experiment Station**

General Technical
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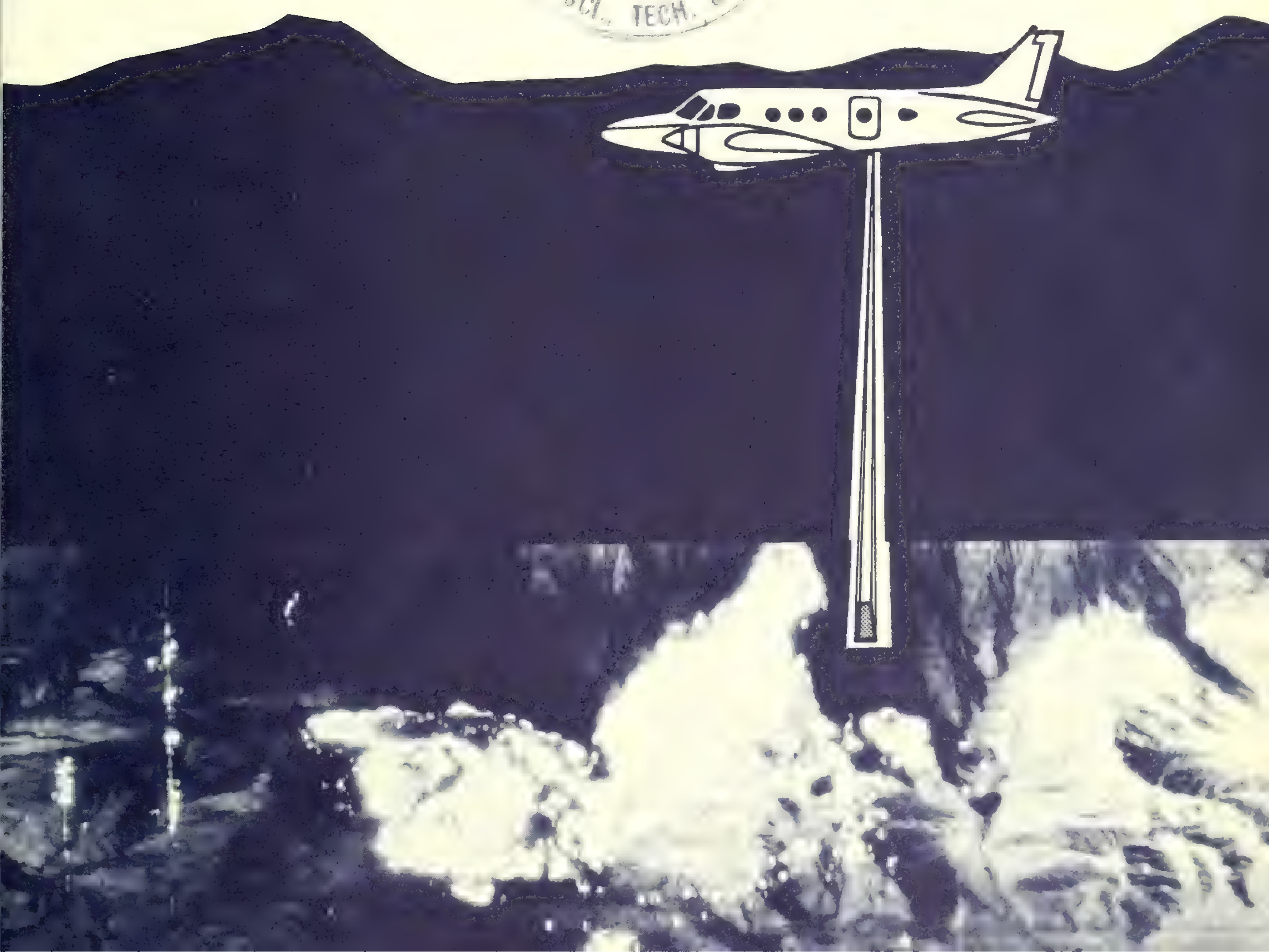
Airborne Infrared Forest Fire Surveillance--A Chronology of USDA Forest Service Research and Development

John Warren and Ralph A. Wilson



THE AUTHORS

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RALPH A. WILSON was research physicist with the FIRESCAN project, at the Northern Forest Fire Laboratory, Missoula, Mont. (1964-1975). Currently he is working in experimental fire behavior at Northern Forest Fire Laboratory.

RESEARCH SUMMARY

In the late 1940's and 1950's forest fire researchers had demonstrated that the time elapsed between ignition and detection accounted for excessive escaped fires and significant burned acreage; detection time was not materially improved with new detection methods--patrol aircraft, improved communications, and other innovations. Thus Project FIRESCAN (Research Work Unit 2105) was initiated in 1962 to work on the forest fire detection problem.

Concurrent with attempts to improve forest fire detection problems, major technological advances were occurring in electronics and photo-optics. Fast-response airborne infrared line scanners were being developed that had obvious application to forest fire detection. The development of lightning location and tracking systems was initiated.

The first research airborne infrared line scanner was acquired in 1962, and research studies were started to examine the physical problems of detecting very small radiation sources obscured by timber canopy and rugged terrain, to study and define the performance requirements of the infrared hardware, and to develop optimal fire patrol strategies and examine the cost effectiveness of airborne infrared fire detection. Studies were performed in cooperation with the Department of Defense to examine problems of common interest, gain access to state-of-art equipment, and to augment research funds. In the fall of 1962, the fire mapping capability was discovered, and the project soon divided its effort into two independent, but technically overlapping, "fire surveillance capabilities--fire detection and fire mapping."

From 1964 to 1966, a fire-mapping crew was detailed to the FIRESCAN project from National Forest Systems to expedite development of fire-mapping operational procedures. The fire-mapping system that was transferred to the Division of Fire Control in 1966, although not the ultimate in technical performance, did provide a badly needed fire intelligence capability.

The technical requirements for detecting small fires in large areas of terrain were much more difficult to resolve. Nevertheless, by 1970 a very sophisticated fire-surveillance system was developed with capability to patrol 2,000 square miles per hour and detect small fire targets with high probability. This system also included greatly improved fire-mapping capabilities.

The fire surveillance system was operationally tested by the Northern Region's Division of Fire Control, in 1971 and 1972, with only marginal success. In retrospect, the airborne forest fire detection system was conceived as a **strategic** fire detection tool; it was designed to have "very large payoff in dollar terms--or in reduction of numbers of escaped fires." The hardware and operational procedures were developed accordingly. However, fire detection is traditionally a **tactical** fire control operation--a fire starts, is detected, and initially attacked by fire control personnel. The resources and plans for implementing a new strategic fire detection system proved to be prohibitive.

By 1974 the Division of Fire Control had developed procedures and skill in using the IR mapping equipment and provision was made to transfer all technical responsibilities to the Boise Interagency Fire Center, Division of Fire Management. The fire detecting capability is available nationally, and is used in critical fire danger situations.

The timely delivery of the IR fire information to fire management personnel has continued to be a serious problem. Image transmission, processing, storage, and display systems using the latest technological advances are being developed by the IR team at BIFC.

During the research and development phase three fire surveillance aircraft with the infrared hardware were acquired; the 1965 mapping unit, the 1965 detection research "breadboard," and the 1974 operational prototype. These three units are obsolescent and are becoming increasingly difficult to maintain in operational readiness. Plans are being made to replace or upgrade these systems to provide reliable performance.

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HISTORICAL REVIEW

Work by J.S. Barrows (1951) and others during the 1940's and 1950's emphasized the need for improved fire detection capability in the Intermountain West. In certain parts of the West, up to 35 percent of the lightning fires were not being discovered until 12 hours after ignition (western zone of USDA Forest Service, Region I, 1931 to 1945, analysis of 18,000 fires.) As many as 10 percent went 72 hours before discovery. Furthermore, analysis showed that the late discoveries accounted for an inordinate number of escaped fires and significant burned acreage (Class E fires). Finally, detection time had not improved materially with "improvements" in detection methods--the introduction of improved communications, patrol aircraft, etc.

Barrows described the problem as follows:

> Once a fire starts, detection is the first requirement in control operations. The efficiency of a detection system is dependent upon its ability to cover the maximum possible area where fires may start, to discover fires quickly enough so that they will be of small size, and describe them accurately with respect to location and behavior. A system that will detect the greatest number of fires in the fastest time at the lowest cost is the major objective.

In 1962, Project FIRESCAN (Research Work Unit 2105) in the Intermountain Forest and Range Experiment Station (INT) was instituted, with Stanley N. Hirsch as project leader. An early association was established with the Electronics Research Laboratory (ERL) at Montana State University; the first cooperative study was to investigate techniques and develop a lightning location system for tracking thunderstorms (Rumpel 1965). The first lightning location efforts bore little fruit because of technical problems. (Most of these problems have been overcome, however, and a recently developed thunderstorm tracking system is currently being tested by the Fire Occurrence Work Unit (RWU 2101) with good preliminary results.)

Concurrent with attempts to improve forest fire detection, major technological advances were occurring in electronics and photo-optics. Military and commercial enterprises were developing sensitive, fast-response airborne infrared line scanners that obviously had potential application to forest fire detection.

In 1962, the project's first infrared (IR) line scanner was installed in a leased Beechcraft AT-11 aircraft. This system produced the first IR imagery of forest fires through smoke palls and of small fires under timber canopies. The technical problems encountered are discussed in detail in the publications listed in the project bibliography (see appendix). Early work concentrated on the operational requirements and utility of airborne IR forest fire detection, including:

1. Cost-effectiveness studies of detection systems by P.H. Kourtz at University of Southern California, Berkeley, Calif.; S.N. Hirsch; and Stanford Research Institute, Palo Alto, Calif.
2. Time history and radiation studies on the characteristics of small fires and obscuration of fire targets by timber canopy overstory, by R.A. Wilson, N. Noste, and B.J. Losensky.
3. Analysis of airborne IR system, performance requirements, and hardware development by F.H. Madden, R.A. Wilson, and S.N. Hirsch.
4. Development of airborne IR fire detection patrol strategy, logistics, and operations tests by P.H. Kourtz, B.J. Losensky, and R.F. Kruckeberg.

A chronological summary of these activities is shown in table 1. Initially, financial support was provided by the USDA Forest Service and the National Science Foundation. Throughout the 1960's, most commercially available IR hardware was developed under military sponsorship (and national security restrictions) and was designed to military requirements. The project undertook cooperative research studies with agencies of the Department of Defense (DOD) to examine problems of common interest, facilitate access to state-of-art equipment, and augment research funds. Cooperating agencies included the Office of Civil Defense for studies and development of techniques for mapping large fires, and the Advanced Research Projects Agency for studies to examine small hot-target identification problems. Because of the developmental nature of this work, project studies prior to 1970 were defined in approved "work agreements" with DOD in lieu of formal research problem analyses and study plans.

Table 1.--Summary of Project Fire Scan Program, 1962-1974

Year	Aircraft	Equipment	Results
1962	Beechcraft AT 11	AAS/5 scanner	First imagery through smoke. Preliminary detection of small fires under forest canopy.
1964	Beechcraft AT 11	AAS/5 (modified for Polaroid readout)	16 flights over wildfires, imagery dropped to fire camp. Data collected on detection probability versus scan angle in four coniferous types.
1964	Aero Commander 500B	AAS/5, Polaroid	49 flights over wildfires, experience in use of imagery for fire control.
	Convair T-29	AAS/5, KD-14 rapid film processor.	No data due to equipment problems.
1965	Aero Commander 500B Convair T-29	Reconofax XI scanner RS-7 scanner, Litton CRT KD-14, tape recorder.	Preliminary evaluation, no data due to equipment problems. Data collected on detection probability versus scan angle in three coniferous and three deciduous timber types.
1966	Aero Commander 500B	Reconofax XI, Dual Polaroid	System delivered to Div. Fire Control for operation.
	Convair T-29	RS-7, Litton CRT, KD-14, tape recorder, APN 81 Doppler	Data collected on detection probability versus scan angle in one coniferous and two deciduous timber types. First fire patrols.
1967	Aero Commander 500B Convair T-29	Reconofax XI, Dual Polaroid RS-7, Litton CRT, KD-14, Target discrimination module, Bendix DRA-12 Doppler	Operational. 21 fire detection patrols.
1968	Convair T-29	RS-7, Litton CRT, KD 14, TDM, DRA-12 Doppler	Equipment modified for 2-color system and to reduce size and weight for installation in smaller aircraft.
1969	Beechcraft King Air	RS-7, Litton CRT, KD-14, TDM, DRA-12 Doppler, 2-color temperature discriminator	Testing and 25 regular fire detection patrols. Two detector problems.
1970	Beechcraft King Air	Same as 1969	Detector problems solved. Successful test. 41 regular fire detection patrols and 15 large forest fires mapped.
1974	Sweringen Merlin	FFS-1 Forest Fire Surveillance (modified RS-7/RS-25)	Procured for National Forest Systems.

In the fall of 1962, the fire mapping capability was discovered while on a routine system checkout flight over a prescribed fire on the Clearwater National Forest (Hirsch 1962). The first imagery of wildfire (the Gravel Creek fire) in 1963 greatly impressed fire control staff officers. Within the next 18 months, the project divided its efforts into two independent but technically overlapping "fire surveillance" capabilities: (1) fire detection and (2) fire mapping (Hirsch 1964; Wilson and Noste 1966; Hirsch and others 1968; Wilson and others 1971).

In 1964, experimental fire mapping equipment was installed in an Aero Commander 500B aircraft. A fire-mapping crew under the leadership of Robert Bjornsen was detailed to the Northern Forest Fire Laboratory (NFFL) to develop fire-mapping operational procedures and expedite the application of this new working tool.

In 1965, the Director, Forest Fire Research, and the Director, Division of Fire Control, agreed to "identify more specifically the information these techniques can record and furnish to the fire boss." In retrospect, involving the user in the development of performance requirements and in the application phase greatly contributed to the success of the IR mapping system, which was transferred to the Division of Fire Control in 1966. The 1966 mapping system was not the ultimate in technical performance, but it was designed to provide badly needed fire intelligence and subsequently proved its worth.

The technical requirements for detecting small fires in large areas of terrain were much more difficult to resolve. In general, the optical-mechanical design of commercial/military scanners was adequate for the forest fire detection mission. However, the IR sensors, the electronic signal processing, and the fire target discrimination logic circuits required extensive study and development work to meet system objectives (Wilson and Noste 1966; Wilson 1968; Wilson and others 1971; Hirsch 1968c, 1971a).

By 1970 a very sophisticated "fire surveillance" system was developed, with capability to patrol several thousand square miles of forested terrain per hour and detect fires as small as 1 square foot with high probability and very low false alarm rates. It also provided a greatly improved capability to produce fire-mapping information. Because of its increased sensitivity and resolution, it could more easily mark spot fires around the fire perimeter, find and mark buried burning material for mopup operations, and provide cleaner and sharper imagery in a continuous strip.

During the fire seasons of 1971 and 1972, the detection system was turned over to and tested operationally (project FIDO) by the Northern Region, Division of Fire Control, with only marginal success (Elms 1972). This operational test was performed at the expense of reduced conventional detection forces on four National Forests in northern Idaho and western Montana; thus, its tactical performance was critically evaluated in specific fire management situations (namely, why did it miss this fire?).

Again, in retrospect, several observations are appropriate. First, fire detection is traditionally a **tactical** fire control operation--a fire starts, is detected, and initial attack forces are dispatched by "front line" fire control personnel. Secondly, the justification and need for improved (strategic) fire detection was a research conclusion that was not fully appreciated nor enthusiastically endorsed by fire control/management. Even though Kourtz (1971) had proved that the detection system had the potential "for very large payoff in dollar terms--or in reduction of numbers of escaped fires--", the neglected realities include: (1) goal and product oriented research must maintain close ties to the end user to be successful; (2) cost effectiveness is immaterial if implementation costs (both dollars and administrative) are prohibitive; and (3) plans for implementation are as important as the solution of the research problem.

Because the forest fire detection capability is available nationally in the airborne IR systems, it is used in critical fire danger situations. While the prototype system (the Beechcraft King Air with Texas Instruments RS-7 scanner) was being tested, the project prepared procurement specifications and monitored the purchase of a second fire surveillance system mounted in a Sweringen Merlin aircraft. These three systems (the original 1966 "mapping" system and the two high-performance "surveillance" systems) are still in use. All three are based at the Boise Interagency Fire Center.

Timely delivery of fire imagery to a fire camp has continued to be a problem since the first mapping system went operational in 1966. The aircraft were fitted with drop tubes to airdrop the imagery into fire camps during daylight hours, visibility permitting; otherwise, the imagery was delivered via ground transportation from the nearest airfield. Ground delivery costs valuable time in too many critical situations. In 1971 and 1972, effort was started to telemeter the fire imagery from the aircraft into fire camp. Briefly, the problems were: (1) the IR scanners produce data (imagery) at rates that would require wide telemetering band widths; (2) these telemetry bands are not routinely available; (3) the range and power of standard telemetry equipment severely limited the aircraft flight procedures; and (4) the costs of equipment are high.

The first low-cost telemetry system using Forest Service (narrow band) radio channels and facsimile reproduction equipment in fire camps produced fire imagery of such low quality and resolution that it was judged "unusable" by fire control staff officers. A second system, developed in 1974 for the FIRESCOPE program in southern California, was expensive, but it produced adequate imagery at fire camp. This system telemetered the composite IR video, synchronization, and roll signals via a leased military telemetry channel (restricted to southern California) to a ground station using a manual tracking directional antenna, and stored the signal on magnetic tape. The tape was then played back through a duplicate of the airborne image recorder-printer--an effective, but cumbersome and expensive procedure.

A series of studies during 1973 and 1974 in cooperation with ERL at Montana State University examined in detail the IR video signal characteristics to identify the fire and terrain mapping information specifically required to be extracted for fire control purposes. The object was to reduce the amount of data in the IR imagery and hence reduce the band width requirements of the telemetry equipment. (Perhaps the immediate need for fire intelligence could be satisfied by an automatically produced line drawing of the fire imagery which is easily transmitted to fire camp, then the IR image photos could be delivered later.) Concurrently, the telemetry system options were examined to

determine the engineering trade-offs between fire information requirements, equipment availability and costs, and system complexity.

In 1974, it was apparent that the primary development work in airborne IR fire surveillance had been accomplished. Because the Division of Fire Control had developed procedures and skill in using the IR equipment for large savings in forest resource and fire suppression costs, it was decided that further technical refinements should properly be within the province of the operational organization. Thus, in 1975 administrative provisions were made to transfer the technical responsibilities and personnel from NFFL (Intermountain Forest and Range Experiment Station) to the Boise Interagency Fire Center, Division of Fire Management. This transfer was completed September 30, 1979.

Since 1975, work has continued on the telemetry "down link" and, in response to increased workload on the IR equipment, plans are in the works to update and expand the airborne IR forest fire surveillance force.

CURRENT STATUS

Fire mapping systems have been used operationally since 1964. The HRB Singer IR scanner was first mounted in an Aero Commander and later in a Beechcraft Queen Air. Subsequently, the King Air (in 1973) and the Merlin (in 1974), both with mapping and detection capabilities, were acquired. The three IR systems have been used nationally (all Forest Service Regions), internationally (Canada), and by many agencies since then. Responsibility for the operation, maintenance, etc. of the IR systems, is with the Division of Aviation and Fire Management (A&FM), Boise Interagency Fire Center.

NFFL personnel have continued support efforts and have worked in an advisory capacity to achieve an orderly implementation of the research efforts into systems hardware and operational use. Technical personnel and laboratory equipment were physically transferred to BIFC during the phaseover, and have now also been organizationally transferred to A&FM, BIFC. Thus the development work has moved systematically from research to an operational unit. The basic research results will continue to be used as a baseline during the design and development of new IR systems to replace the aging units in use.

Development efforts typically require at least three iterations: (1) a breadboard, (2) a prototype or engineering model, and (3) a production or operational unit. In the airborne infrared systems, equipment up to and including the Queen Air could be considered as experimental; the King Air as a prototype; and the Merlin as an operational system. Note that the Merlin was adapted from earlier designs and used prior technology (table 2). All three airborne systems, however, were pressed into operational use, and the decision to acquire modern, interchangeable, truly operational systems is still pending.

Table 2.--Current status of fire surveillance systems

Item	System		
	HRB Singer (Queen Air)	T.I. RS-7 (King Air)	R.I. RS-25 (Merlin)
Scanner (receiver)			
Design age	1962	1962-69	1962-73
Date acquired	1964	1965	1974
Operational date	July 1966	Summer 1971	October 1974
Source	Purchased by OCD and "given" to Forest Service.	Purchased by FS Research, used about 6 years, then transferred to NFS.	Modification of RS-7 and AAS-18 to produce RS-25.
Image producer			
Type	Polaroid	KD-14 wet chem.	EMR Dry Silver
Design age	1965	Late 50's.	1969-1970
Source	Lab prototype Built by NFFL	One of 14 military prototypes built and then dropped. Went to dry silver, then back to wet chem.	Note: a later model dry silver image producer was procured by NFFL for Firescope in 1975. Modified for wet chem. in 1975-76.

The three present airborne IR scanning systems are becoming increasingly more difficult to maintain and keep up to performance standards because of age, lack of planned cyclic replacement, changes in electronics, industry, and so on. There is a large and growing list of parts that are difficult or impossible to acquire. Also, the three systems are basically without commonality, interchangeability, or backup. Recognizing this situation, the Regional aviation and fire managers unanimously agreed to support the acquisition of new IR line scanning systems at their Oklahoma City meeting in November 1978. The recommended action is to procure four identical (or at least interchangeable to the major component level) systems--one for each of the three aircraft and one for the maintenance facility. The latter is to be used as a ready source of spares, as a test bed for proposed modifications, and for trouble-shooting replaced components. Preliminary specifications have been prepared and will be reviewed, updated, and maintained ready for upgrading to procurement level specifications when the system replacement money is available. The new systems will be based on FIRESCAN research and on the operational experience with the present three systems. The new systems will incorporate modern technology, designs, and techniques.

Image transmission, processing, storage, and display systems are now under development by the IR development and test team at BIFC. These systems will use the latest technological advances to provide rapid image transmission and reception from plane to fire command post. The first of the three iterations (experimental) has been assembled and used on real forest fires.

The operational design will greatly speed up the interpretation process and offer enhancement and display options that will greatly improve the usefulness and timeliness of fire information. It will also be available for coupling into information from other systems as described further in a discussion on the future. Figure 1 presents some of the features of the planned operational system. Procurement of the first operational system is planned for fiscal year 1981.

FUTURE PROSPECTS

The near-term (less than 5 years) plans described above will provide up-to-date airborne IR scanning systems as the primary IR fire intelligence systems for large fire mapping and detection missions. Ground image receiving/processing/storage/display systems will be available for use at the fire command post. Rapid delivery and interpretation of IR imagery for timely use by the fire boss (or incident commander) and his staff should become commonplace instead of a long-sought luxury.

Future plans call for tie-ins with computer models, such as fire rate-of-spread, and vivid interactive displays of current and predicted fire positions, electronic overlays of fire and fuelbreaks, lines to be built, and other characteristics that will aid in decisionmaking on active fires.

Voice communications via satellite from fire command post to agency headquarters (or to any telephone) will become standard for fire operations. Technical feasibility was demonstrated more than 3 years ago (Warren 1975). This will be accomplished with small-diameter (1 meter) transportable parabolic antennas and corresponding transmitting and receiving equipment. This capability may then be followed by satellite data communications and image transmission. Selective use of detection missions needs to be exploited much more in the future. With the expanding use of Remote Automatic Weather Stations (RAWS) to provide improved resolution to the National Fire-Danger Rating System (NFDRS), and the introduction of the Automatic Lightning Detection System (ALDS) to pinpoint potential fire-causing lightning strikes, a fire detection flight over the area of concern can find small, recently ignited fires and preclude some major large fires.

To sum up, the future will bring improved performance and reliability in the airborne IR systems and timely delivery and interpretation of imagery to the fire staff. In addition, the coupling of the IR information systems to other systems and to evolving computer models should multiply the benefits and the usefulness of available information.

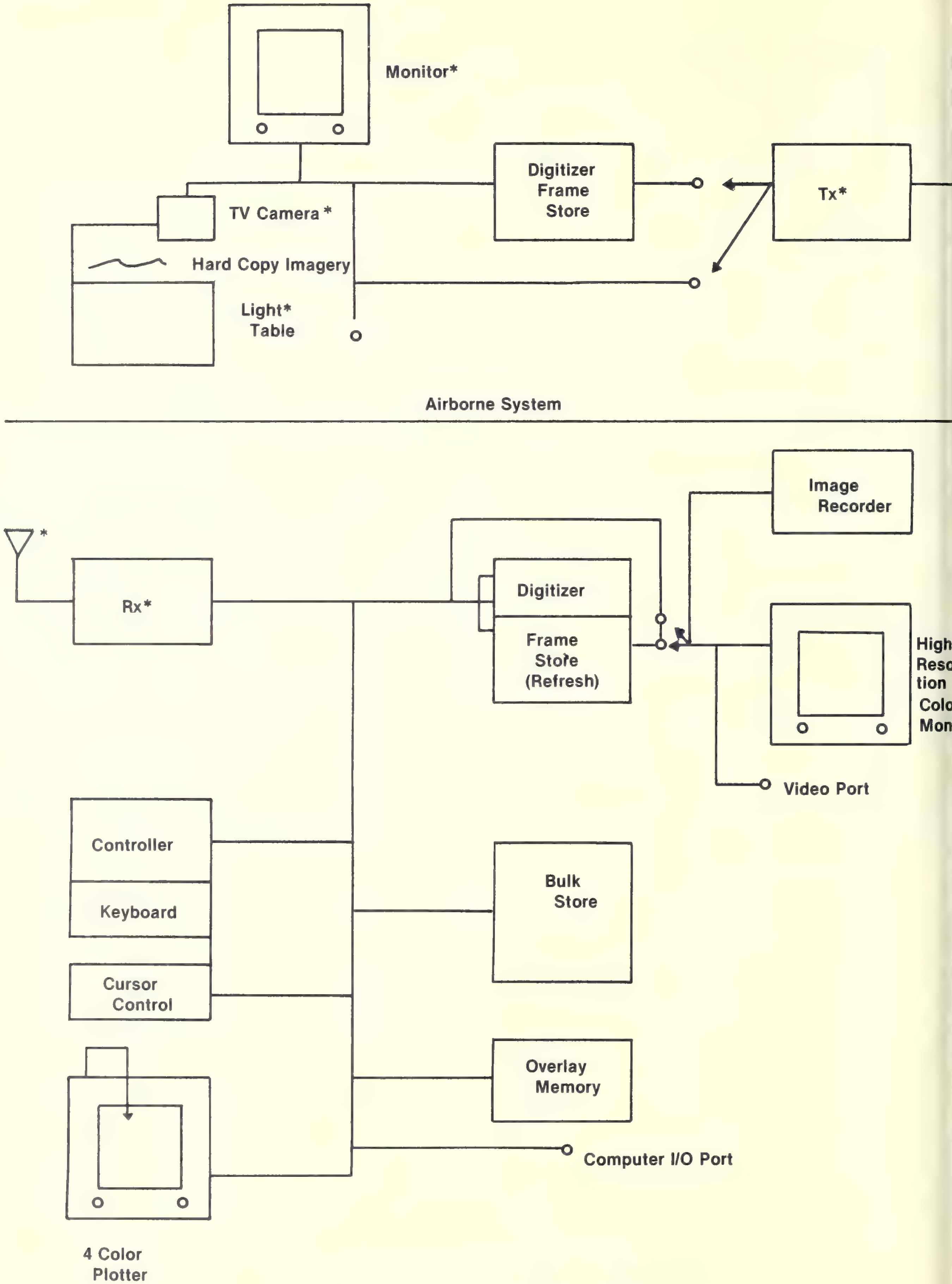

Figure 1.--Image transmission processing system.

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Provides a brief history of USDA Forest Service infrared (IR) research, current status of image systems in development, and future plans and projected uses of infrared imagery. Describes status of Forest Service IR systems research, development, testing, and usage up to the time that those functions and the IR development team were transferred from research to National Forest Systems, Division of Aviation and Fire Management, Boise Interagency Fire Center, Boise, Idaho.

KEYWORDS: infrared, airborne, surveillance, fire, mapping, detection, FIRESCAN, history

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The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 273 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

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